Gilbert Cady

INTERNATIONAL GEOLOGICAL CONGRESS

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GREAT BRITAIN 1948

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PART IX (9)

PROCEEDINGS OF SECTION H

THE PLIOCENE-PLEISTOCENE BOUNDARY

LONDON
1950

INTERNATIONAL GEOLOGICAL CONGRESS

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General Editor: A. J. Butler

PART IX

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THE PLIOCENE-PLEISTOCENE BOUNDARY

Edited by
K. P. OAKLEY

LONDON
1950

Section H, The Pliocene - Pleistocene Boundary, met on three occasions during the Session. The Chairmen at these meetings were as follows :—

August 26th	**Professor W. B. R. King**
August 28th	**Professor D. M. S. Watson, for a joint meeting with Section K.**
August 31st	**Professor W. B. R. King**

The Secretary of the Section was Dr. K. P. Oakley.

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THE PLIOCENE - PLEISTOCENE BOUNDARY

INTRODUCTION

Opening Remarks to the Discussion held on August 26th

By W. B. R. KING, Chairman
Great Britain

THE Pleistocene period has been defined on two entirely different principles—first on the basis of fauna and second on climatic conditions. Lyell (1839) used the percentage of living forms as the criterion. Historically, however, it would appear that the term Quaternary was erected to include the time that man existed on the earth, and that later the beginning of this division of time was considered to be contemporaneous with the base of the Pleistocene. Prestwich, who probably was the greatest authority on the strata of this time, realized the difficulties. In his text-book *Geology: Chemical, Physical and Stratigraphical*, vol. ii, 1888, p. 441, he emphasizes the "Absence of a Base-line " and while in a footnote suggests that it may really be best to have the base of the Pleistocene at the base of the Red Crag, nevertheless decides to place it at the top of the Chillesford Clay. This line has been accepted by the majority of British geologists in the past.

Recently Professor R. F. Flint has summarized the evidence and proposes that the term Pleistocene Epoch should refer to the period of time " which is characterized by repeated climatic cooling, involving repeated conspicuous glaciation in high and middle latitudes, repeated pluvial phenomena in middle and low latitudes, and related worldwide fluctuations of sea-level . . . It is also marked by the appearance and intercontinental migrations of the modern horse, cattle, mammoths, camels and man." In this we see an attempt to equate the two methods of definition. The method which is based on the assumption that the spread of land-vertebrates is an approximate time-line, proposed by Haug, is much favoured by many recent workers, particularly the prehistorians and vertebrate palaeontologists. We must ask, however, should either of these criteria, change in land fauna or in climate, be used in drawing stratigraphical boundaries? In defining all other systems the changes in fauna which are considered most important are those in the shallow-water marine facies. In theory the arrival of the first *Equus* or the growth of the first Alpine glacier would make a convenient starting point for Pleistocene time; but in practice these are not feasible criteria.

In stratigraphy as in palaeontology it is as advisable to have a " type locality " as it is to have a " type specimen." It gives a definite basis to which argument of a theoretical nature can be related. If it were possible to agree upon a type-locality where the boundary between the Pleistocene and Pliocene can be seen, then future work could be tied to that " bench-mark." It is to be admitted that the exact bedding-plane which is chosen for the dividing line would be an arbitrary one. The first step is to agree on the boundary in *one* place, where there are visible fossiliferous deposits spanning the dividing line. Lyell in his earlier works placed great reliance on the Italian successions. In Italy there is abundant development of marine deposits (*Calabrian*), as well as prolific continental deposits (*Villafranchian*), at no great distance from the great Alpine centre of glaciation, thus providing some hope of obtaining correlation between these chief facies.

If general agreement could be reached as to whether the boundary should be at the base of, or at the top of, the Calabrian—Villafranchian it should be a matter of no great difficulty to choose a section where it would be possible to agree on a definite stratum marking the boundary in that locality. From this " bench-mark " future correlations can be made between the various facies and areas where rocks of Pleistocene age occur.

RECOMMENDATIONS OF COMMISSION APPOINTED TO ADVISE ON THE DEFINITION OF THE PLIOCENE - PLEISTOCENE BOUNDARY

While the discussions of Section H were taking place, the Council of the Congress appointed a Temporary Commission to advise on the question of the definition of the Pliocene-Pleistocene Boundary.

The following served as members of the Commission:—

Kirk Bryan (U.S.A.)
G. Dubois (France)
A. T. Hopwood (Gt. Britain)
W. B. R. King (Gt. Britain)
L. S. B. Leakey (Kenya)
C. I. Migliorini (Italy)
K. Milthers (Denmark)
Hallam L. Movius, Jr. (U.S.A.)
K. P. Oakley (Gt. Britain)
L. L. Ray (U.S.A.)
I. M. van der Vlerk (Netherlands)
D. N. Wadia (India)
D. M. S. Watson (Gt. Britain)
E. J. Wayland (Bechuanaland)
F. E. Zeuner (Gt. Britain)

At the conclusion of the Eighteenth Session, on September 1st, 1948, the Council unanimously accepted the recommendations of the Commission, which were as follows:

(1) The Commission considers that it is necessary to select a type-area where the Pliocene-Pleistocene (Tertiary-Quaternary) boundary can be drawn in accordance with stratigraphical principles.

(2) The Commission considers that the Pliocene-Pleistocene boundary should be based on changes in marine faunas, since this is the classic method of grouping fossiliferous strata. The classic area of marine sedimentation in Italy is regarded as the area where this principle can be implemented best. It is here too that terrestrial (continental) equivalents of the marine faunas under consideration can be determined.

(3) The Commission recommends that, in order to eliminate existing ambiguities, the Lower Pleistocene should include as its basal member in the type-area the Calabrian formation (marine) together with its terrestrial (continental) equivalent the Villafranchian.

The Commission notes that according to evidence given this usage would place the boundary at the horizon of the first indication of climatic deterioration in the Italian Neogene succession.

It is understood that the Geological Society of Italy is now working on the problem of selecting a type-locality for the precise definition of the boundary, and it is hoped that a report of their findings will be made at the Nineteenth Session of the Congress. Meanwhile, some of the implications of the proposed definition have been discussed in *Nature*, 163, p. 186, Jan. 29, 1949; *Man*, 1949, 72.

LES LIMITES ET LES CORRÉLATIONS DU QUATERNAIRE AFRICAIN*

Par C. ARAMBOURG

France

RÉSUMÉ

L'auteur, tenant compte de la classification du Quaternaire africain adoptée en 1947 par le Congrès de Nairobi, indique que l'étude des faunes fossiles des gisements nord-africains permet d'établir certaines corrélations stratigraphiques entre les deux régions.

Un niveau repère très important parce qu'il s'étend à tout le bassin méditerranéen est fourni par les couches rouges éluviennes à industrie Levalloiso-moustérienne postérieures à la dernière plage soulevée de la mer à *Strombus bubonius*, et contemporaines de la régression marine Würmienne; elles correspondent au dernier grand Pluvial et équivalent au début du Gamblien. Certains autres termes du Quaternaire africain sont représentés par divers gisements: ceux de Palikao et du Lac Karâr correspondent au sommet du Kamasien inférieur; celui de Tihodaïne (Sahara) au Kamasien supérieur. La série des grès sublittoraux du Maroc avec le poudingue de base à *Archidiskodon* cf. *recki* englobe tout le Kamasien. D'autre part l'étude des gisements Villafranchiens Constantinois poursuivie par l'auteur depuis plusieurs années, lui a montré qu'ils équivalaient, par leur faune, à ceux du Kaguérien dont ils renferment l'association caractéristique: *Anancus*, *Elephas* cf. *planifrons*, *Stylohipparion*, *Lybitherium*, etc., et devaient, par conséquent être intégrés à la base du Pléistocène; leur équivalence stratigraphique avec ceux du Villafranchien d'Europe justifie l'opinion de Haug, faisant débuter le Quaternaire avec l'apparition des genres modernes *Bos*, *Equus*, et *Elephas*.

* This paper was read at the joint meeting with Section K held on August 28th, and is printed in full in Part XI of the Report.

THE PLIOCENE - PLEISTOCENE BOUNDARY IN THE BRITISH DEPOSITS

By D. F. W. BADEN-POWELL

Great Britain

ABSTRACT

In the well-known sequence in East Anglia, the Pliocene-Pleistocene Boundary would come as low as the base of the Coralline Crag, if Lyell's definitions of the Pliocene, based on the percentage of living species among the fossil marine mollusca, were taken literally. At the other extreme, some British geologists have only counted the Glacial Series in this district as belonging to the Pleistocene, leaving the Cromer Forest Bed as Pliocene in the addition to the Coralline, Red, Norwich and Weybourne Crags.

If an intermediate point of view is taken, either the Norwich Crag or the Red Crag can be considered as the Lower Pleistocene; of these two alternatives, there is a slight preference for placing the boundary line at or near the base of the Red Crag, partly because this seems to be the earliest zone in which *Elephas meridionalis* appears, and also because the marine mollusca of the Red Crag reflect the beginning of the climatic deterioration which foreshadowed the Pleistocene Ice Age.

THE EAST ANGLIAN SEQUENCE

The main British deposits which have been classified as Pliocene or Pleistocene are situated in East Anglia, where the general sequence is:—

Glacial Series (with marine bands)

Cromer Forest Bed Series (partly non-marine)

Weybourne Crag Chillesford Beds Norwich Crag	} Icenian Series

Norfolk Stone Bed (non-marine)

Butley Crag Newbourne Crag Walton Crag	} Red Crag Series

Suffolk Bone Bed (non-marine)

Coralline Crag

Suffolk Bone Bed (non-marine)

The members of this sequence, arranged with the oldest bed at the bottom, are marine unless otherwise stated. Of the non-marine deposits, the Cromer Forest Bed has yielded a large vertebrate fauna, and vertebrate remains are known also from the Norfolk Stone Bed and from the Suffolk Bone Beds. Both marine mollusca and vertebrates are therefore available from the sequence as a whole for correlation, and for helping to form an opinion on the lower limit of the Pleistocene. Apart from East Anglia, the Diestian deposits near Lenham, Kent, are generally acknowledged as Pliocene, and a small outcrop of shell beds at St. Erth, Cornwall, is most nearly correlated with the Walton Crag of East Anglia.

DATING BY THE MARINE SHELLS

When Lyell (1833, pp. 53–4) defined the terms " Newer Pliocene " and " Recent " (later called

Pleistocene), he based his opinion approximately on the following percentages of living species of shells present as fossils:—

Recent (including Sicilian), more than 95 per cent living.

Newer Pliocene, about 33–95 per cent living.

It is difficult, for various reasons, to calculate these percentages very accurately, but the results for some of the marine beds in East Anglia are approximately as follows:—Coralline Crag, 62 per cent; Walton Crag, 64 per cent; Newbourne Crag, 68 per cent; Butley Crag, 87 per cent; Weybourne Crag, 89 per cent; and the Corton Beds (interglacial), 88 per cent. These figures show that if Lyell's definition is taken literally, all the Crag deposits, as well as the interglacial Corton Beds, would count as Newer Pliocene. But Lyell himself did not use his method consistently, for he classed the Crags as Older Pliocene. The practice of the Geological Survey (see Clement Reid, 1882, p. 85) and Harmer (1920, p. 488), has been to include the Cromer Forest Bed as the top of the Pliocene, leaving the Glacial Series as Pleistocene. This arrangement was found convenient for the local geological mapping.

On the other hand, a lower limit for the base of the Pleistocene was in effect proposed by S. V. Wood and Harmer (1872), who included the Weybourne Crag and the Cromer Forest Bed Series in their " Lower Glacial " Division, although they refused to adopt the terms Pliocene and Pleistocene as such. Moir (1924, p. 236) even considered the Bone Bed below the Red Crag as indicating a stratigraphical break of sufficient importance to count as the lower limit of the Pleistocene. The palaeontology of the Walton Crag is rather opposed to Moir's opinion, as this deposit is in some sense a passage bed between the Red and the Coralline Crags, but on the other hand, it is most significant that from Waltonian times onwards the cold types of marine mollusca make their appearance in increasing numbers. This makes an interesting comparison with Gignoux's Calabrian in the Mediterranean area.

Summarizing the evidence from the marine shells, we have the following choices for the base of the Pleistocene Series among the East Anglian deposits:—

1. The base of the Glacial Series (in East Anglia). This most nearly agrees with Lyell's original definition, but introduces serious difficulties.
2. The base of the Norwich Crag, a marked stratigraphical break.
3. The base of the Red Crag. This is the point of arrival of the cold fauna.

DATING BY THE VERTEBRATES

The Cromer Forest Bed Series and the Norfolk Stone Bed contain *Elephas meridionalis* and *Elephas antiquus*, and therefore count unquestionably as Pleistocene in accordance with current ideas. The fauna from these beds was originally reported in the Cromer and Norwich Memoirs of the Geological Survey. The Suffolk Bone Beds contain various bones and teeth, many of which are derivative, but specimens good enough for specific identification are not common, and in recent years many of the sections have been closed down, thus hindering collecting. In spite of these difficulties, it seems established that *Elephas meridionalis* and *Mastodon arvernensis* have been found in the Bone Bed below the Red Crag, and that *Elephas antiquus* does not occur at this horizon; but the records are contradictory on this latter point. In any case, it seems certain that *Elephas meridionalis* has not been recorded from the base of the Coralline Crag, and seems, therefore, to have appeared for the first time between the Red and Coralline Crags.

The correspondence of the advent of this species with the beginning of the immigration of cold marine mollusca is significant, and is strikingly similar to the correlation between the Villafranchian and the Calabrian worked out by Gignoux in the Mediterranean area.

CONCLUSION

The East Anglian evidence seems to amount to this; there is insufficient evidence on palaeontological grounds for placing the base of the Pleistocene as early as the Bone Bed below the Coralline

Crag, or as late as the Glacial Series above the Cromer Forest Bed. It should therefore coincide with a significant zone between these two extremes; that is, either at or near the base of the Red Crag, or at the base of the Norwich Crag.

In favour of the inclusion of the Red Crag as Pleistocene, there is the arrival of *Elephas meridionalis* and the incoming of cold marine conditions; against this decision, it may be said that this arrangement leaves only the Coralline Crag and Diestian Lenham Beds as Pliocene, and in other parts of Europe the Pliocene would be similarly reduced to very narrow limits. If the Stone Bed below the Norwich Crag were chosen as the base of the Pleistocene, *Elephas antiquus* or its relatives would become the zonal fossil among the vertebrates, and the arrival of a more " modern " marine fauna than that of the Red Crag would correspond with this horizon, but it must be admitted that this does not seem as significant a natural boundary as that at the base of the Red Crag. From the East Anglian evidence, the recognition of an enlarged " Lower Pleistocene " formation at the expense of the Pliocene is perhaps the best decision, especially as it includes the first signs of climatic deterioration which was the beginning of the Pleistocene Ice Age.

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LA LIMITE DU PLIOCÈNE ET DU QUATERNAIRE AU MAROC

Par G. CHOUBERT

Morocco

RÉSUMÉ

La limite du Pliocène et du Quaternaire au Maroc est définie par un cycle d'érosion gigantesque mis en route par la dernière phase tectonique alpine (villafranchienne). Ce cycle qui évolue dans le Sud et l'Est du Maroc, selon les lois de l'érosion désertique, aboutit dans ces régions à la création d'une surface d'érosion qu'on peut appeler surface " fini-villafranchienne " ou pré-sicilienne. C'est sur cette surface que viennent se déposer les premières formations quaternaires, formations siciliennes.

La surface fini-villafranchienne sépare deux époques d'évolution de relief: le Pliocène qui avec le cycle d'érosion de la fin du Villafranchien crée le relief actuel, et le Quaternaire, au cours duquel ce relief est retouché, et fignolé.

En outre, le Quaternaire forme un système climatique nettement individualisé. On peut le traduire par une courbe climatique générale dont le maximum correspond aux croûtes calcaires tyrrhéniennes, encadrées par les limons rouges du Milazzien et du Grimaldien. Les minima tempérés sans dépôts continentaux généralisés, se plaçent au Sicilien et au Flandrien. Ce système est indépendant des systèmes précédents, pliocène, miocène et oligocène, dont les maxima sont les climats rubéfiants d'accumulation du Villafranchien, du Pontien et de l'Aquitanien.

On sait que l'utilisation des changements de faunes (par évolution progressive ou par renouvellement plus ou moins brutal) pour la subdivision du temps en ères, périodes, étages, etc. . ., se trouve en défaut à la fin de l'échelle stratigraphique. Les étages deviennent ici trop courts pour que les faunes, tout au moins les faunes marines, aient le temps d'évoluer. Cette insuffisance du critère paléontologique devient particulièrement génante à la fin du Miocène: le Sahélien qui théoriquement devrait être le représentant marin du Pontien, devient un étage fantôme qu'on ne saît plus reconnaître. Les auteurs sont obligés d'établir les pourcentages des formes miocènes et pliocènes pour pouvoir classer un terrain dans le Tortonien, le Sahélien ou le Pliocène. Plus la connaissance de ces faunes avance, plus les listes des fossiles caractéristiques se raccourcissent, car chaque étude nouvelle nous apprend qu'un tel fossile pliocène existait déjà au Miocène et inversement une telle forme purement Miocène survit au Pliocène. L'exemple de la faune extrêmement riche du Dar Bel Hamri est suffisamment démonstratif: depuis L. Gentil les spécialistes continuent leur discussion au sujet de son âge sahélien ou pliocène (Chavan, 1944; Lecointre et Roger, 1943). D'autres critères sont donc nécessaires pour séparer ces deux périodes.

Heureusement, au Maroc, en dehors des zones fort limitées, où le régime marin fut continu du Miocène au Pliocène, la grande régression pontienne, caractérisée par un climat rubéfiant d'accumulation et suivie par la phase tectonique dite " post-pontienne," puis par un cycle d'érosion que celle-ci a déclanchée, permettent à coup sûr de séparer ces deux périodes. Le critère paléontologique devenant insuffisant, c'est le critère orogénique—la discordance—qui prend ici toute son importance. Le Pliocène commence par une transgression, d'ailleurs sensiblement concomitante d'un changement climatique (Choubert, 1945).

Les mêmes considérations s'appliquent à la limite entre le Pliocène *sensu lato* et le Quaternaire, car même malgré un refroidissement notable, qui en Europe et en Méditerranée marque le Sicilien, le changement des faunes qu'il provoque ne semble pas suffire pour définir à coup sûr les formations quaternaires. Ainsi, les éléments froids comme *Cyprina islandica*, considérés généralement comme caractéristiques du Sicilien, apparaissent comme l'a montré M. Gignoux (1913) déjà au Calabrien. De

(*Légende: Pour "plaisancienne" lire "pliocène."*)

Fig. 1.

même, d'après les études récentes de C. Arambourg à Omo, les faunes des Mammifères pliocènes persistent en Afrique au début du Quaternaire (Arambourg, 1947).

Au Maroc la succession des phénomènes géologiques à la limite du Pliocène et du Quaternaire est sensiblement la même qu'entre le Miocène et le Pliocène. Comme celle du Pontien, la régression villafranchienne qui fait suite à la transgression du Pliocène ancien, est caractérisée par le climat rubéfiant d'accumulation. Une phase tectonique dite " villafranchienne " (ou post-villafranchienne), suivie d'un cycle d'érosion gigantesque terminent cet étage.*

La marche de cette érosion que j'appellerai érosion de la *fin du Villafranchien*, semble être saccadée. Dans les endroits propices (vallées profondément encaissées, comme l'Oued Beth, certains oueds des montagnes (Dresch, 1933, 1941) elle a laissé des replats du type des terrasses quaternaires, comportant même parfois du matériel détritique roulé (p.ex. terrasse de 150 m. à éléments de granites en haut de la montée de l'Oued Beth vers Meknès). On attribue à ce cycle d'érosion les replats et terrasses supérieurs à 100 m. d'altitude relative. Leur étagement serait dû, soit à des secousses tectoniques, soit comme au Quaternaire, à des arrêts au cours d'un soulèvement isostatique, provoqué par le travail de l'érosion.

L'étude des formes de terrain, permet d'établir que lors de ce cycle, toute la partie Nord Ouest du Maroc fut soumise à l'érosion normale. L'érosion désertique a sévi dans le Sud et l'Est: au Sud du Haut Atlas, dans la partie Est de cette chaîne, dans la Moulouya, les Hauts Plateaux; ainsi qu'à l'Ouest dans l'ensemble Bahira-Haouz. J. Dresch avait déjà établi dans le Haouz que cet évidange de la fin du Villafranchien a pu raboter une tranche de terrain atteignant 250 m. (Dresch, 1933). Le même travail fut effectué dans les " feijas " sur le pourtour de l'Anti-Atlas, car les falaises des Hammadas, couronnées par le calcaire lacustre pliocène atteignent 250 m. de hauteur (Choubert, 1945). Le creusement des vallées dans la zone soumise à l'érosion normale atteint la même hauteur, p.ex. 300 m. pour l'Oued Beth, soit 100 m. au Quaternaire et 200 m. à la fin du Villafranchien (Dresch, 1941). C'est donc ce cycle d'érosion extrêmement active, faisant suite à une phase tectonique d'exhaussement général, qui a donné au Maroc sa configuration actuelle.

Il faut ajouter que dans toutes les régions affectées, pendant ce cycle, par l'érosion désertique, le travail de l'érosion a abouti dans les zônes à roches tendres (schistes, marnes) à un aplanissement parfait. J'appellerai cette surface "*fini-villafranchienne*". Elle n'est autre que la surface pré-sicilienne par laquelle il convient de terminer le Pliocène et commencer le Quaternaire. Elle se retrouve dans toutes les plaines internes ou périphériques, séparées par des reliefs appalachiens, qui caractérisent les régions accidentées du Maroc Sud-Oriental.

Sous quel climat a eu lieu ce cycle d'érosion gigantesque? Ce n'était certainement plus le climat rubéfiant d'accumulation, car ce stade climatique prit fin avec la phase tectonique d'exhaussement du Villafranchien. Il est vraisemblable que ce climat de la fin du Villafranchien fut assez pluvieux, car les produits de démantellement étaient entraînés à la mer. Dans certaines cuvettes internes du domaine atlasique, comme p.ex. aux Beni Amir (partie Est de la cuvette de Bahira-Tadla), où le travail de cette érosion fut pratiquement nul, les couches rouges villafranchiennes sont couronnées par une dalle " terminale " de calcaire lacustre (Choubert, 1946). On pourrait peut être la considérer comme contemporaine de cette phase pluvieuse (ou tout au moins d'une partie de cette phase) par laquelle se termine le Villafranchien.

Il faut souligner l'intensité et la vitesse de l'érosion qui a eu lieu lors de cette phase climatique, et cela indépendamment de son mécanisme normal ou désertique. L'exhaussement important de tout le système atlasique par la phase tectonique villafranchienne, ne semble pas pouvoir expliquer à elle seule cette énergie de destruction. Comme les paléoclimats rubéfiants d'accumulation (Choubert et Bryssine, 1946; Choubert, 1948) on ne pourra vraisemblablement l'expliquer que par des causes climatiques n'agissant plus actuellement comme p.ex. une teneur de l'atmosphère en CO_2 plus grande qu'actuellement, ou une cause cosmique quelconque.

* En réalité la succession des phénomènes semble être un peu plus complexe. Ainsi Laffitte indique la présence dans le Sahel d'Alger d'une autre discordance qui se situe entre le Pliocène inférieur marin et le Villafranchien (Laffitte, 1948).

On peut admettre que la transgression sicilienne est venue s'étaler sur la surface fini-villafranchienne. Cependant la discordance entre le Sicilien et le Villafranchien n'a encore pu être observée directement au Maroc. Tout le long de la Meseta côtière, le Villafranchien rouge est encore très mal connu. On y connaît surtout des grès pliocènes tantôt marins, tantôt dunaires, comportant à leur base un niveau marin à faune bien connue à Huitres et Pectens (*P. planomedius*). M. Gigout qui étudie cette zone côtière considère ces dunes comme appartenant déjà au Villafranchien (Gigout, 1947). Les formations attribuables au Sicilien et caractérisées par une faune froide à *Acanthina crassilabrum*, *Trochatella trochiformis* et *Littorina* (Lecointre, 1926), viennent reposer sans discordance angulaire tantôt sur ce Pliocène, tantôt directement sur le substratum primaire ou crétacé jusqu'à une altitude oscillant autour de 100 m. Ce sont également des grès marins ou dunaires avec de rares lumachelles (Choubert et Marçais, 1947; Lecointre, 1926). Leur distinction des formations pliocènes dans cette zône couverte de croûtes et de limons est fort difficile (Gigout, 1947).

La disposition est plus nette au Nord et au Sud de la Meseta. Au Nord, dans la région de Port-Lyautey (Oued Fouarat), nous venons de décrire J. Marçais, E. Ennouchi et moi, des formations attribuables au Calabrien avec une faune différente du Sicilien de la côte (Choubert, Ennouchi et Marçais, 1948). C'est d'une part une faune marine d'Huitres et de Pectens, semblable au Pliocène inférieur, mais caractérisée par une très grande abondance de *O. cucullata* et de sa variété, *cornucopiae* Lecointre et de *O. serresi*; d'autre part une faune de Mammifères à *Mastodon* (*Anancus*) *osiris* Arambourg et *Elephas meridionalis* du type archaïque.* Malheureusement le Sicilien connu non loin de là (Sidi Bou Knadel) n'est nulle part en contact observable avec ces formations.

Au Sud de l'Atlas, le Villafranchien typique sous son faciès habituel de conglomérats, grès, limons et argiles rouges, existe près d'Agadir (Choubert, 1945). Il recouvre ici en concordance les grès du Pliocène ancien, à faune de Robinson, et est plissé avec lui. A Agadir même, le Villafranchien est moins net. On ne peut lui attribuer que quelques bancs de conglomérats et de grès rouges redressés, affleurant entre la plage et la mer. Par contre le Pliocène ancien est largement représenté entre Agadir même et le vallon de Tildi: il est rasé par une surface d'érosion d'une altitude (absolue) de 100 m. La discordance est ici manifeste et l'attribution de ces replats, ne comportant malheureusement plus de formations marines, au Sicilien se justifie par la présence en contrebas de tous les autres niveaux classiques du Quaternaire (Choubert, 1945), contenant des faunes marines abondantes.

Les choses sont bien plus nettes à l'intérieur du Maroc, surtout dans les zones où l'érosion désertique a persisté pendant le Quaternaire, et où l'influence du climat doux et humide du Tyrrhénien—" le climat de la croûte " (Choubert, 1948)—n'a pas effacé les formes morphologiques anciennes. On trouve dans ces zones les quatre regs quaternaires, emboités les uns dans les autres. J'ai montré ailleurs (Choubert, 1946, p. 911) que trois de ces regs contenaient des industries lithiques:

Le reg ancien (attribué au Milazzien) a fourni de l'Abbevillien.

Le reg moyen (Tyrrhénien) et les plaines encroûtées sont caractérisés par l'Acheuléen et le Levalloisien.

Le reg récent et les plaines limoneuses (Grimaldien) contiennent des industries moustéroides.

Le reg le plus ancien, plus élevé que le reg ancien ne contient pas d'industries. C'est le reg attribué au Sicilien, généralement mal conservé, qui recouvre la surface fini-villafranchienne, dans laquelle sont emboitées les surfaces successives des regs suivants.

L'altimétrie relative des regs n'est généralement pas caractéristique, car chacun représente une surface topographique plane dans le détail mais plus ou moins inclinée et ondulée dans son ensemble. On ne peut en tirer argument que dans les cas particuliers comme par exemple à El Ayoun du Dra, où le creusement de l'Oued Dra est déjà influencé directement par les oscillations du niveau de l'Océan et où l'érosion quaternaire a suivi les lois de l'érosion normale. La surface d'érosion des environs du poste d'El Ayoun du Dra qui n'est autre que le reg le plus ancien établi sur la surface fini-villafranchienne,

* Les formations siciliennes des environs de Rabat ont fourni un *Elephas meridionalis* du type *cromerensis* que Arambourg classe actuellement parmi les *Elephas recki* Diétrich (Arambourg, 1938, 1947; Ennouchi, 1948).

descend en pente douce vers l'Oued et s'arrête à une altitude relative de 100 mètres. En contrebas, à une altitude de 50–60 m., sont conservés des lambeaux d'une haute terrasse qui nous a fourni, à P. Taltasse et moi, une industrie sur éclat d'une facture très archaïque qui, d'après l'avis du regretté Ruhlmann, pourraît être contemporaine de l'Abbevillien.*

A cause du puissant exhaussement par la phase tectonique villafranchienne, les caractères morphologiques des surfaces d'érosions antérieures et postérieures à cette phase peuvent être toutes différentes. Il se produit en morphologie un phénomène comparable par sa nature aux discordances stratigraphiques, que je vais illustrer par deux exemples: celui des gorges d'Aouli près de Midelt et celui de la chaîne des Jebilet.

Dans toute la cuvette de la Haute Moulaya étudiée d'abord par G. Dubar, puis actuellement par M. Reynal, les surfaces d'érosion successives depuis le Pliocène (et même le Pontien) jusqu'au Quaternaire, sont sensiblement parallèles et résultent d'une évolution du relief par cycles successifs d'érosion désertique. Les regs quaternaires emboités, remarquablement développés autour de Midelt, s'emboitent dans la surface fini-villafranchienne (reg le plus ancien), au dessus de laquelle les buttes témoin jalonnent les surfaces plus anciennes. Or, dans sa traversée du massif primaire d'Aouli, la Moulouya s'encaisse brusquement et coule dans des gorges à plus de 250 métres de profondeur. Aux approches des têtes des valons affluents, on peut observer que les regs quaternaires, larges et sensiblement horizontaux jusque là, s'inclinent, se rétrécissent et passent progressivement aux terrasses étagées qui suivent la pente rapide de ces vallons. Par contre les surfaces antérieures à ce surcreusement de la fin du Villafranchien, continuent la plaine de la Haute Moulouya. Elles déterminent le pays tabulaire, d'une altitude moyenne de 1400 m., qui s'étale de part et d'autre des gorges de la Moulouya, à 250 m. au dessus de l'Oued.

Les Jebilet sont bordés au Nord par la plaine de la Bahira vaste cuvette à remplissage continental pontien et pliocène à peine errodé, au Sud par celle du Haouz où l'érosion villafranchienne a travaillé énergiquement (Dresch, 1941). Au Quaternaire les deux plaines sont caractérisées par un régime de comblement terrigène, l'érosion de caractère désertique ne jouant qu'un rôle secondaire.

En venant de Mazagan par le plateau des Ganntour (Bahira occidentale), on est frappé par la faible hauteur des Jebilet; on traverse cette chaîne à plat, le " col " emprunté par la route (alt. 530 m.) étant à peu près au niveau de la Bahira (475 à 500 m.). Au delà de ce " col " commence la descente longue de 30 km. qui aboutit au pont de Tensift (alt. 375 m.) à 150 m. plus bas que le " col." On traverse un relief montagneux intensément rajeuni, une sorte de " relief en creux ", taillé par l'érosion de la fin du Villafranchien du Tensift et de ses affluents dans le massif primaire des Jebilet. La surface du comblement terminal pontien et pliocène dans le Haouz, est jalonnée par les cailloutis du sommet du Jebel Tilda (alt. 468 m.) près de Chichaoua. La hauteur de la tranche rabotée est ici également voisine de 150 m. car l'altitude de la plaine de Chichaoua est de 325 m. environ.

Des formations quaternaires puissantes sont venues combler le Haouz. Mais on peut observer la surface inclinée, mais absolument nivelée, du glacis paléozoique sur la route de Casablanca à Marrakech entre les Jebilet et le Tensift.

La différence d'altitude entre la plaine de Ben Guérir ou Bahira centrale (450 m. au milieu, 500 m. à Sidi Bou Othmane) et le Haouz (398 m. au pont de Tensift de la Route de Casablanca, 440 à Marrakech) est bien moindre.

Par contre, sur la route de Kasba-Tadla, la pente est inversée: venant du Nord par la trouée d'El Kelaa des Srharna (alt. de la plaine à El Kelaa 450 m.) on monte de 150 m. pour arriver au Haouz Oriental (alt. 550 à 600 m.). Or la plaine d'El Kelaa (Bahira Orientale), recèle sous le Quaternaire le même remplissage néogène légèrement ondulé que plus à l'Ouest. Il se termine par des calcaires lacustres pliocènes. Dans le Haouz Oriental, ces terrains de comblement sont également à peu près

* La même industrie se retrouve dans la terrasse marine de la même altitude, immédiatement au Sud de l'embouchure de l'Oued Noun (O. Assaka).

complets et se terminent par les cailloutis pliocènes* qui affleurent par endroit, au milieu de la plaine (Dresch, 1941).

A la suite des mouvements villafranchiens et de l'érosion de la fin du Villafranchien, les pentes des deux plaines, sensiblement horizontales à l'origine, sont actuellement inversées. Voici les altitudes sur trois transversales dont les extrêmes sont distantes de 100 km.†

BAHIRA

475	Route de Mazagan Centre de la plaine	Calcaire lacustre pliocène sous quelques métres de Quaternaire
450	Route de Casablanca Centre de la plaine	Calcaire lacustre pliocène
410	Près de la Tessaout Centre de la plaine	Calcaire lacustre pliocène sous plus de 50 m. de Quaternaire

HAOUZ

225 (468)	Bordure de la vallée du Tensift au Nord de Chichaoua (Jebel Tilda près de Chichaoua)	Surface fini-villafranchienne couverte de Quaternaire (Cailloutis pliocènes)
440	Marrakech	Quaternaire puissant sur surface fini-villafranchienne
600	Haouz Oriental	Cailloutis pliocènes

L'importance de l'inversement des pentes est dûe au travail du réseau hydrographique du Tensift à la fin du Villafranchien dans le Haouz; elle est diminuée par un comblement quaternaire puissant (50 m.) dans la Bahira: cailloutis de la Tessaout passant à l'Ouest à des limons anciens.

En outre, le Tensift quaternaire s'encaisse par rapport à la plaine fini-villafranchienne du Haouz. Son encaissement devient sensible en aval de Marrakech. Les terrasses quaternaires le suivent: d'abord peu différenciées, elles s'écartent de plus en plus pour atteindre en définitive leurs altitudes théoriques dans le tronçon aval, influencé directement par les oscillations du niveau de l'Océan (p.ex. au pont de la Route Casablanca-Mogador).

Ces quelques exemples suffisent à démontrer que le cycle d'érosion à la fin du Villafranchien crée une profonde coupure dans l'évolution du relief. La surface fini-villafranchienne sépare deux époque nettement différentes: l'une a esquissé le relief actuel; l'autre, avec ses quatre stades de creusement (pluviaux) séparés par des temps d'arrêt ou des comblements (interpluviaux), l'a retouché, tantôt en l'exagérant, tantôt en l'adoucissant. Pratiquement on n'est jamais en peine, tout au moins à l'intérieur du Maroc, pour distinguer la part du Quaternaire dans la naissance du relief actuel et cela dans les zones à régime climatique et, par conséquent, à régime d'érosion (ou de comblement) tout différent.

* Les gorges de l'Oued Lakhdar montrent une double discordance: la première entre un dôme complexe de Lias et le Pontien, la deuxième entre ce Pontien et des cailloutis pliocènes, les deux moulant le dôme liasique, mais avec un rejeu du pli de plus en plus faible.

† Les altitudes données pour la Bahira sont légèrement inférieures à ce qu'elles devraient être, à cause d'une légère reprise du synclinal par les mouvements villafranchiens; cette différence est compensée par un recouvrement quaternaire plus ou moins développé.

Ainsi à part de rares cas, la phase d'érosion de la fin du Villafranchien nous apparaît d'un seul tenant; tandis qu'on peut, généralement différencier les quatre stades de l'érosion quaternaire dûes à l'alternance des pluviaux et des interpluviaux.

Au point de vue climatique, les interpluviaux quaternaires sont également bien définis. J'ai signalé ailleurs la succession de ces climats (Choubert, 1946, p. 511; Choubert et Bryssine, 1946) qui permet d'établir une courbe climatique générale à un seul maximum, englobant la totalité du Quaternaire. Elle comporte le " climat de la croûte," exagération du climat rubéfiant spéciale au bassin méditerranéen, dans sa région culminante (Tyrrhénien); les climats rebéfiants d'accumulation (Milazzien et Grimaldien) l'encadrent; enfin des climats tempérés (ou froids) non rubéfiants caractérisent les minima (Sicilien et Flandrien).* Le Quaternaire est donc un système climatique indépendant et bien individualisé. Il fait suite dans le temps à un autre système climatique, qui d'une durée plus longue, englobe le Pliocène. Ce dernier se compose d'abord d'une phase humide et vraisemblablement tempérée à dépôts lacustres et à conglomérats gris, précédés peut-être d'une phase sans dépôts continentaux. L'ensemble de ces deux phases est semble t-il plus ou moins concomitant de la transgression du Pliocène inférieur.† Le maximum climatique est marqué par le climat rubéfiant d'accumulation du Villafranchien. Enfin la branche descendante de cette courbe climatique pliocène correspond au cycle d'érosion de la fin du Villafranchien. Elle aboutit au minimum climatique du Sicilien.

En remontant dans le temps, on retrouve un troisième système semblable, mais encore plus long et beaucoup moins symétrique, ayant son maximum rubéfiant au Sarmatien-Pontien. Un quatrième maximum serait marqué par les formations rouges de l'Aquitanien. Il se trouve que chacun de ces systèmes correspond à une période géologique: l'Oligocène, le Miocène et le Pliocène. Le Quaternaire en tant qu'ère avec son système climatique à lui, souligné par la périodicité des glaciations (pluviaux), cadre donc parfaitement avec les subdivisions stratigraphiques précédentes. Pour des raisons que nous ignorons, les systèmes climatiques successifs deviennent de plus en plus courts à mesure qu'on monte dans l'échelle stratigraphique. Ainsi, la durée du dernier système, celui du Quaternaire, n'équivaut qu'à un sous-étage des périodes précédentes.‡

Il se trouve que les phases de climat rubéfiant de l'Aquitanien, du Pontien et du Villafranchien, coincident avec les grandes régressions provoquées vraisemblablement par des causes d'ordre orogénique. En outre, le Pontien et le Villafranchien se terminent chacun par une phase tectonique importante de sorte que les systèmes climatiques miocène et pliocène se terminent chacun par un cycle d'érosion.

Les causes orogéniques n'ont, semble t-il, plus agi au Quaternaire, car avec la phase tectonique villafranchienne les mouvements tectoniques alpins ont pratiquement pris fin. On observe encore, des affaissements locaux accompagnés parfois de subsidence dans les zones faibles. Mais des véritables inclinaisons des couches comme on en connaît en Tunisie, sont tout à fait exceptionnelles au Maroc. Je ne peux signaler qu'un seul exemple de tel pendage tectonique, ne pouvant pas s'expliquer par une inclinaison originelle dûe à la sédimentation sur une surface topographique inclinée.§ C'est le cas

* Je rappellerai que les climats rubéfiants d'accumulation ne semblent plus exister actuellement à la surface de la terre, car les dépôts flandriens sont toujours noirs, gris ou jaunes. Ce seraient des paléoclimats dûs à une exagération d'un des facteurs climatiques, tels que la teneur de CO_2 en atmosphère, vraisemblablement en rapport avec des causes cosmiques (Choubert et Bryssine, 1946; Choubert, 1948): variations de la radiation solaire, influençant le règne végétal et par là l'équilibre gazeux de l'atmosphère ou un autre phénomène cosmique inconnu.

† Dans l'état actuel de nos connaissances du Pliocène de l'Afrique du Nord, on ne peut préciser si la phase climatique humide des calcaires lacustres, lignites et conglomérats gris, qui précède le climat villafranchien rouge, est entièrement postérieure à la transgression du Pliocène inférieur, comme cela ressort des exemples algériens (Laffitte, 1948), ou bien si la régression de la mer pliocène a eu lieu au cours de cette phase. De toute façon, il semble qu'une autre phase climatique, sans dépôts continentaux, l'aurait précédé. Elle correspondrait au cycle d'érosion post-pontienne et peut-être à une partie de la durée de la transgression du Pliocène ancien.

‡ On peut évaluer la durée du Pliocène, Miocène et Oligocène respectivement à 6, 12 et 16 millions d'années (Gignoux, 1942). Le Quaternaire, d'après les évaluations les plus larges, atteindrait à peine 1 million d'années.

§ Contrairement à ce que j'ai pensé primitivement (Choubert, 1945).

de la flexure sud-atlasienne à Agadir, où le niveau marin milazzien est affecté d'un plongement SE de 15° à 20°, ce qui l'abaisse de la cote de 40 m. (derrière l'Hotel Terminus) à la cote de 15 m. (près du bâtiment des Travaux Publics).

On est donc amené à rechercher l'explication des transgressions et des régressions quaternaires dans la théorie d'eustathisme glaciaire, qui les relie aux oscillations climatiques, dont la courbe se superpose à la courbe du système climatique général. Le système climatique quaternaire est donc à ce point de vue une exception par rapport aux systèmes précédents. Son classement en " ère " indépendant satisfait donc l'esprit.

Enfin l'argument classique pour commencer le Quaternaire avec les formations siciliennes déposées sur la surface fini-villafranchienne, est l'apparition des premières industries humaines. Cependant nous sortons ici du cadre du présent travail qui s'appuie uniquement sur des exemples marocains, car la " pebble industry " n'est pas encore connue au Maroc.

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PLIOCENE E PLEISTOCENE NEL COLLE DI S. COLOMBANO AL LAMBRO (LOMBARDIA).

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RÉSUMÉ

L'étude géo-paléontologique de " Colle di S. Colombano al Lambro (Lombardia) " vient de mettre en évidence l'existence du Quaternaire marin (Calabrien), transgressif sur le Plaisancien inférieur: en conséquence le Calabrien devrait être séparé du Pliocène et considéré comme faisant partie d'un autre cycle sédimentaire. Les faunes ont aussi démontré que la base du Calabrien, caractérisée par un conglomérat essentiellement organogène, correspond à un mileau marin côtier d'eaux tempérées ou tempérées chaudes.

ATTRAVERSO lo studio geologico e paleontologico del Colle di S. Colombano al Lambro, recentemente eseguito e che sarà pubblicato al completo in altra sede, sono state compiute tra l'altro, grazie anche alla collaborazione micropaleontologica del Dott. E. di Napoli, alcune osservazioni, che riguardano sotto vari aspetti il problema dei rapporti tra Pliocene e Pleistocene nella Val Padana.

Questo rilievo collinoso, che si estende isolato nella bassa pianura lombarda tra il Lodigiano ed il Pavese, appena ad occidente della confluenza del Fiume Lambro nel Po, è stato in passato oggetto di numerose ricerche geologiche e paleontologiche. Di esso mancava ancora però una ricostruzione stratigrafica, fondata sullo studio parallelo delle macro e microfaune, considerate sotto l'aspetto ambientale.

Le serie di cui abbiamo notizia, relative alla località in oggetto, sono dovute a Sacco (1891), a Porro e Anelli (1928). Esse diversificano tra di loro: in particolare Sacco distingue i seguenti orizzonti, in ordine discendente:

Sahariano	Loess argilloso, rosso-giallastro o grigiastro, con lenticelle sabbioso-ghiaiose.
Astiano	Sabbie giallo-grigiastre con ciottolini (facies Fossaniana). Sabbie giallastre. Sabbie marnose straterellate.
Piacenziano	Sabbie marnose grigiastre con fossili. Marne argillose grigio-bluastre, riccamente fossilifere, con lenti calcaree e madreporiche. Marne argillose bluastre.

Porro e Anelli dànno invece la seguente serie, dall'alto al basso:

Quaternario antico: Depositi in prevalenza sabbiosi e conglomeratici, diffusi nella parte occidentale della collina e fin presso le falde su tutto il versante meridionale.

Pliocene superiore (*Calabriano*)*:* Arenarie sabbiose chiare giallastre con intercalazioni di strati induriti, rossicci, con Pettini ed altre bivalvi.

Arenarie con intercalazioni di argille a *Cardium* e *Turritella*, preponderanti nella parte inferiore e appoggiate ad uno strato di

Calcare madreporico di 1–3 m di spessore, oppure conglomerato madreporico a ciottoli calcarei e di rocce cristalline di tipo alpino.

Miocene (*Tortoniano-Elveziano*)*:* Argille un pò sabbiose, chiare, senza stratificazione distinta, con pochi fossili (*Ancillaria glandiformis*, *Eudiolum*, *Ringicula*, *Dentalium*) e in stretto legame con conglomerati, argille con ciottoli

sparsi e banchi di arenarie (Tortoniano). Marne bianchiccie del tipo dello Schlier, straterellate con intercalazioni di arenarie e di sabbie con ciottoli (Elveziano).

LA SERIE STRATIGRAFICA

Le ricognizioni eseguite in superficie ed i dati ricavati dallo studio dei campioni estratti da un sondaggio di circa 100 m di profondità, eseguito recentemente a scopo idrico nella località di Miradolo, a S-O dell'abitato di S. Colombano al Lambro, hanno portato alla ricostruzione di una serie stratigrafica, che differisce sensibilmente dalle precedenti. Essa dall'alto al basso è la seguente:

Quaternario continentale: Diluvium antico,

(6) Depositi argillosi e sabbiosi rossigni con piccole lenti ghiaiose e concrezioni calcaree, passanti al basso a sabbie siliceo-calcaree, spesso micacee, poco argillose, più chiare con ciottoli sparsi di quarzo, micascisti, gneiss e calcari spesso molto alterati, circa m 4.

Quaternario marino: Calabriano,

(5) Sabbie gialle e biancastre sottili, siliceo-calcaree e micacee, con veli più o meno spessi di molasse e arenarie rossastre e limonitiche, intercalate specialmente verso il basso da zone a straterelli di argille sabbiose grigiastre, circa m 20.

(4) Argille sabbiose grigio-verdastre chiare, con abbondante fauna a *Turritella tricarinata* Br. sp., m 5.

(3) Argille straterellate verdastre molto fossilifere con *Venus multilamella* Lk. sp., *Cardium echinatum* L., var. *mucronata* Poli, *Cardium edule* L., *Pectunculus insubricus* Br. sp., *Nassa serraticosta* Brn. sp., *Chama placentina* Defr. ecc., m 3.

(2) Calcare conglomeratico di scogliera a *Lithothamnium*, rossiccio, più o meno cariato e friabile, costituito da un impasto di fossili spesso frammentati, ciottoli calcarei e cristallini di tipo alpino, m 3.

Pliocene: Piacenziano.

(1) Marne sabbiose grigio-verdastre e argille marnose più chiare straterellate, con rari frammenti di molluschi indeterminabili, letti di ciottoli calcarei e cristallini alternati da sottili veli sabbiosi, con abbondante microfauna.

Mentre il Calabriano è da tempo noto nel Colle di S. Colombano per gli studi paleontologici di alcuni Autori, tra cui Patrini (1916) e Mariani (1888), il Piacenziano, già indicato da Sacco nella sua serie, ma non suffragato da elementi paleontologici, è ora per la prima volta riconosciuto con sicure prove in questa zona. Più precisamente il Piacenziano viene a sostituirsi nell'assegnazione al Tortoniano, a cui Porro e Anelli attribuivano, per la presenza di pochi fossili di tipo miocenico, i terreni degli stessi affioramenti da noi esaminati.

Non è possibile tuttavia escludere ancora l'esistenza di qualche lembo miocenico nella zona di S. Colombano; Miocene che, d'altra parte, sappiamo costituire il substrato dei terreni pliocenici della pianura lombarda. Ci limiteremo pertanto all'esame ed alla documentazione della serie stratigrafica da noi ricostruita, con riguardo ai termini di essa che interessano i rapporti tra Pliocene e Pleistocene marino.

La parte di questo studio, che riguarda le microfaune, è dovuta al Dott. E. di Napoli.

PIACENZIANO

I campioni esaminati, appartenenti a questo piano, si riferiscono al liv. 1 della serie stratigrafica sopradescritta. Sono costituiti da argille marnose grigio-biancastre, sabbiose e friabili, con rari frammenti di macrofossili: al lavaggio lasciano un residuo abbondante di sabbia quarzosa a grana media e fine, grosse squame di mica alterata e qualche ciottoletto calcareo; la microfauna è abbondante ed in buono stato di conservazione.

In tutto sono state identificate un centinaio di specie, di cui le più frequenti e significative sono:

Cibicides pseudoungerianus Cushman.
Globigerina bulloides d'Orbigny.
Globigerinoides triloba Reuss.
Uvigerina rutila Cushman and Todd.
Bulimina pyrula d'Orbigny.
Bulimina pupoides d'Orbigny.
Bulimina ovata d'Orbigny.
Siphonina reticulata Czjzek.
Robulus, specie varie.

La mancanza di Miliolidae, di forme tipicamente litorali e l'associazione delle specie sopracitate permettono di stabilire un ambiente nettamente marino e, tenendo conto della facies argilloso-sabbiosa del sedimento, un livello compreso tra i limiti delle zone neritica e batiale.

Le seguenti specie, che costituiscono circa il 15% dell'intera microfauna, sono considerate estinte nel Pliocene:

Uvigerina rutila Cushman and Todd.
Listerella perparva Cushman.
Planularia lanceolata d'Orbigny.
Vaginulinopsis inversa Costa.
Eponides tenera var. *stellata* Silvestri.
Marginulina costata var. *coartata* Silvestri.
Nodosaria pleura Costa.
Marginulina cristellarioides Czjzek.
Vulvulina pennatula var. *italica* Cushman.

Solo le due ultime specie sembra che siano limitate al Miocene: esse sono però rappresentate da due individui ciascuna in un solo campione, nel quale si nota pure un sensibile aumento delle forme planctoniche. Data la facies argilloso-sabbiosa del sedimento che le contiene, non possiamo escludere che si tratti di individui rimaneggiati. D'altra parte dobbiamo tener presente che nella parte bassa del Pliocene dell'Appennino vengono comunemente riscontrate varie forme di tipo miocenico, tra cui quelle citate. Entrambi i casi potrebbero spiegare la presenza di molluschi di tipo miocenico, segnalati nel livello inferiore della serie di S. Colombano da Porro e Anelli (1928), e che li hanno indotti ad attribuirlo al Tortoniano.

L'associazione di forme e in particolare le specie sopracitate permettono di riferire i campioni esaminati alla parte inferiore del Piacenziano.

Spiccate analogie si osservano con faune coeve di Castellarquato nel Piacentino, di Cà di Roggio nel Modenese e con quelle ormai famose del Ponticello di Savena presso Bologna.

CALABRIANO

Questo piano è stato riconosciuto in base allo studio della micro e macrofauna, ricavate dai livelli 2–4 della serie stratigrafica affiorante e dai livelli corrispondenti del sondaggio di Miradolo.

La microfauna.—Si presenta più abbondante nei campioni provenienti dal sondaggio citato: qui il Calabriano ha inizio a 100 m di profondità (circa m 28 sotto il liv. mar.), con un tipico conglomerato organogeno, nel quale oltre a numerosi molluschi, prevalentemente di piccole dimensioni, Briozoi e Litotammi, è presente un'abbondante microfauna. Prevalgono le forme seguenti:

Amphistegina lessoni d'Orbigny.
Elphidium crispum Linneo.
Gypsina globulus Reuss.
Eponides repanda Parker and Jones.
Discorbis orbicularis Terquem.
Cibicides lobatulus Walker and Jacob.

Molto abbondanti sono pure *Quinqueloculina* e *Spiroloculina.* Sono presenti inoltre numerosi e ben sviluppati individui di *Gaudryina tumidula* Cushman e *Textulariella trochoides* d'Orbigny. Le Globigerinidae sono rappresentate da due sole specie con pochissimi individui.

Nei livelli immediatamente sovrastanti al conglomerato le microfaune si mantengono sempre abbondanti, mentre nella parte più alta della serie si osserva un impoverimento ed una specializzazione delle faune, che risultano constituite in prevalenza da *Rotalia beccari.*

Le associazioni faunistiche ed i caratteri litologici indicano chiaramente chi si tratta di un deposito marino costiero, ed in particolare la prevalenza nella microfauna di *Rotalia beccari* potrebbe indicare un ambiente salmastro.

Alcuni campioni della serie affiorante (liv. 2–3) si presentano invece quasi tutti con faune scarse come specie, con prevalenza di *Rotalia beccari, Elphidium crispum, Elphidium decipiens, Nonion*

granosum, *Nonion boueanum*, *Textularia aciculata*: associazione che indica un ambiente costiero. Altri campioni degli stessi livelli contengono faune a sola *Rotalia beccari* o a *Nonion granosum*; mancano quasi completamente le Miliolidae. Qualche campione infine (liv. 4–5) presenta faune di ambiente nettamente marino, con abbondanti *Bulimina*, *Valvulineria bradyiana* Fornasini e qualche *Cassidulina laevigata* var. *carinata* Cushman.

Le caratteristiche litologiche del conglomerato organogeno, in cui prevalgono forme calcaree, l'abbondanza di *Amphistegina* e *Gypsina* associate a Miliolidae, abbondanti sia come numero di specie che di individui, indicano un ambiente marino con acque temperate o temperate calde.

In tutta la serie calabriana le uniche forme a tendenza fredda sono state riscontrate in un campione del sondaggio di Miradolo a m 53 di profondità, equivalenti a m 19 circa s.l.m., e riferibile al liv. 5 della serie stratigrafica. Si tratta di:

Anomalina balthica Schröder.
Nonion sloani d'Orbigny.
Nonionella turgida Williamson,

rappresentati da pochi esemplari. In questo stesso campione le Globigerinidae che, a differenza di quanto si osserva in tutti gli altri campioni, costituiscono circa il 30% della fauna, sono rappresentate da esemplari scarsi e molto piccoli. Le Cassidulinidae, pure presenti, sono troppo scarse per poter essere considerate indicative.

Non si sono riscontrate finora specie estinte. Si osservano invece varie forme, di cui alcune sembrano avere preso inizio nel Calabriano; altre non erano ancora note allo stato fossile. Le specie più frequenti sono:

Discorbis opercularis d'Orbigny.
Anomalina balthica Schröder.
Nonion sloani d'Orbigny.
Quinqueloculina ariminensis d'Orbigny.
Quinqueloculina contorta d'Orbigny.
Quinqueloculina variolata d'Orbigny.
Sigmoilina edwarsii Schlumberger.
Reussella spinosissima Costa.
Globigerina adriatica Fornasini.

Le forme esaminate e le caratteristiche ambientali delle loro associazioni sono comuni a vari depositi calabriani dell'Appennino e del sottosuolo della Pianura Padana.

Viene così ancora una volta confermata l'esistenza del Calabriano nel Colle di S. Colombano al Lambro, in concomitanza anche ai risultati dello studio della macrofauna.

La macrofauna.—Questa proviene dai livelli 2–4 della serie stratigrafica affiorante. Sono state determinate oltre 100 forme, dall'esame delle quali si nota che la quasi totalità è costituita da specie litorali della zona delle laminarie e delle coralline. In particolare, considerando le forme dominanti nei livelli 4 e 3, esse vengono ad esser poste nella zona a *Turritella* e *Chlamys*, diffusa tra m 60 e m 100 circa di profondità, concordemente alla facies argilloso-sabbiosa del sedimento che le contiene. Il livello 2, a facies detritico-organogena, rappresenta invece un deposito di bassofondo in prossimità della spiaggia, formatosi ad una profondità compresa tra m 10 e m 25 circa. Lo attesta tra l'altro la presenza dei *Mytilus*, che vivono a profondità minime. Notevole anche in questo livello la presenza del *Cardium* (*Cerastoderma*) *lamarki* Reeve e del *Cerithium* (*Thericium*) *vulgatum* Brug., forme salmastre che possono indicare un ambiente costiero prossimo allo sbocco in mare di un corso d'acqua.

La prevalenza dei molluschi è costituita da forme banali, prive di significato stratigrafico. Quasi tutti vivono ancora nel Mediterraneo e nell'Atlantico; il numero delle forme estinte è assai ridotto e nessuna di esse è scomparsa dal Mediterraneo prima del Calabriano.

In quanto al clima, la fauna denota essersi depositata in acque temperate o temperate calde.

Le specie e varietà di interesse stratigrafico sono:

Nassa (*Amycla*) *semistriata* Br. sp. aff. *calabrensis* Gign.: scomparsa col Calabriano.
Venus (*Ventricola*) *lamellosa* De Rayn.: estinta col Calabriano.
Leda fragilis Chemn. var. *consanguinea* Bell.: varietà finora ritenuta estinta col Calabriano.
Nassa (*Hima*) *serraticosta* Brn. sp.: estinta col Siciliano.
Chama placentina Defr.: estinta col Siciliano.

Della *Leda fragilis* Chemn. var. *consanguinea* Bell. è stata osservata da Trevisan (1937 e 38) la persistenza durante il Siciliano, nel giacimento del Fiume Belice (Agrigento). A questo proposito occorre notare, conformemente ai risultati di De Stefani (1942) e di Tamajo (1936), che con l'aumentare della conoscenza dei giacimenti del Siciliano una distinzione in base ai fossili tra questo piano e il Calabriano e, in qualche caso persino, il Calabriano inferiore va facendosi sempre meno netta, per la " sopravvivenza " di forme ritenute estinte.

Gli elementi paleontologici però di cui disponiamo concordano per un riferimento al Calabriano, anche se devesi riscontrare nei terreni in esame l'assenza di " forme fredde," caratteristiche del Calabriano e del Siciliano, e che invece, come è dato rilevare, mancano nelle facies litorali, preferendo un habitat più profondo. Questo fatto, già notato da Gignoux (1913), è stato recentemente messo in evidenza da Ruggieri (1943 e 44) nello studio di alcune faune del Siciliano calabrese e romagnolo di facies litorali, superanti le 150 specie ciascuna e tutte prive di " ospiti nordici."

Una sola forma, la *Chlamys septemradiata* Müll., proveniente dal conglomerato organogeno, è considerata specie ad affinità nordiche: è forma che vive nel Mediterraneo dal Pliocene, assumendo grande sviluppo nel Calabriano e Siciliano.

Vero è che la presenza di specie boreali come la *Cyprina islandica* è stata indicata nel giacimento di S. Colombano da Taramelli (1916), la cui citazione è stata riferita e ripresa da Autori successivi. Nell'esplorazione metodica del terreno non sono stati però trovati esemplari o frammenti riferibili alla *C. islandica*, nè le ricche raccolte paleontologiche locali di altri ricercatori e attualmente in corso di studio presso l'Istituto di Geologia della Università di Milano, hanno rivelato la presenza di tale specie.

CONSIDERAZIONI E CONFRONTI

I limiti tra Pliocene e Calabriano possono essere definiti in base a criteri faunistico-climatici e stratigrafici, applicabili alla zona di S. Colombano e, per ora, alla parte sud-orientale della Pianura Padana.

Le associazioni microfaunistiche del Calabriano rispetto a quelle plioceniche presentano le seguenti caratteristiche:

(*a*) Percentuale di specie estinte molto bassa (da 0 a 5% circa).

(*b*) Comparsa di forme nuove che hanno preso origine agli albori del Calabriano.

(*c*) Comparsa di forme che per la prima volta entrano a far parte delle faune mediterranee all'inizio del Calabriano.

(*d*) Comparsa di forme che attualmente non vivono più nel Mediterraneo, ma che sono diffuse in altri mari.

Dal punto di vista climatico osserviamo che il conglomerato organogeno, rappresentante la base della trasgressione calabriana, si è deposto in acque temperate o temperate calde e comunque a temperatura più elevata di quella che attualmente si riscontra lungo le coste italiane, dove non vivono più *Amphistegina* e *Gypsina*. Le microfaune dei livelli direttamente sovrastanti al conglomerato denotano in generale una diminuzione sensibile della temperatura, che ha provocato la comparsa di faune specializzate fredde a *Cassidulina* e ad *Anomalina balthica*, nonchè la migrazione di forme di mare

profondo verso acque più litorali, già segnalate in vari punti della Pianura Padana (di Napoli Alliata, 1946; Selli, 1946).

A. S. Colombano questa associazione fredda non si osserva, data probabilmente la facies più i torale dei sedimenti.

La variazione di temperatura, che sembra essere stata generale e sensibile durante il Calabriano, potrebbe essersi limitata nella zona di S. Colombano a determinare l'impoverimento delle faune con relativa scomparsa delle forme a tendenza temperata o temperata calda (Miliolidae, Amphisteginidae, Gypsinidae); all'impiccolimento delle Globigerinidae osservato nel campione di m 53 del sondaggio di Miradolo; alla specializzazione delle faune a *Bulimina* e a *Valvulineria bradyiana* o a *Nonion granosum*.

Alla formazione delle faune a sola *Rotalia beccari* può avere invece influito anche una diminuzione della salsedine.

In quanto alla macrofauna calabriana di S. Colombano, vogliamo rimarcare quanto segue:

(*a*) Percentuale di specie estinte molto bassa (circa 5%).

(*b*) Prevalenza di forme attualmente ancora viventi nel Mediterraneo.

(*c*) Assenza di forme tipicamente fredde (solo una, la *Chlamys septemradiata* Müll., è considerata specie ad affinità nordiche).

(*d*) La fauna denota un clima temperato o temperato caldo.

Analoghe condizioni faunistico-climatiche sono state riscontrate, come è stato già detto, nel Pleistocene calabrese e romagnolo.

Dal punto di vista stratigrafico infine è chiara l'esistenza di una discordanza rappresentata dal diretto contatto del Calabriano sui depositi del Piacenziano. Questa discordanza è osservabile in più punti verso il piede della collina, dove le argille marnose piacenziane affiorano con perdenze accentuate (fino a 50°) generalmente da SE e SO e sulle quali poggia il conglomerato organogeno, piegato con leggerissimo anticlinale.

Questa trasgressione, caratterizzata dal tipico conglomerato, è diffusa in vari punti del sottosuolo della Pianura Padana (presso Rovigo nel Veneto, presso Parma in Emilia e a Casalpusterlengo in Lombardia) e nell'Appennino modenese. Le faune calabriane di queste località presentano le stesse caratteristiche delle nostre, indicando condizioni ambientali molto simili, per quanto quelle di S. Colombano appartengano ad una facies, che è la più litorale finora nota nella Pianura Padana.

CONCLUSIONI

Da quanto sopra succintamente esposto, risulta che nel Colle di S. Colombano al Lambro il ciclo pliocenico termina col Piacenziano inferiore. Il Calabriano, depositatosi trasgressivamente su di esso, viene quindi a far parte di un nuovo ciclo sedimentario.

Allo stato attuale delle conoscenze, questa trasgressione sembra essere diffusa nella Pianura Padana sud-orientale e nell'Appennino modenese ed assumere quindi un significato regionale. In base a questi fatti il Calabriano dovrebbe essere distinto dal Pliocene e far parte del Pleistocene.

D'altra parte, mentre finora il criterio per la distinzione del Calabriano dal Pliocene era basato sulla comparsa di forme di mare freddo (*Cyprina islandica*, ecc.), a S. Colombano l'inizio del Calabriano è contrassegnato dal conglomerato organogeno basale con faune di mare temperato caldo. In tal modo sembra che la trasgressione sia qui avvenuta prima che si facesse risentire l'influenza delle mutate condizioni climatiche, che hanno determinato l'introduzione degli ospiti freddi.

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THE PLIO-PLEISTOCENE BOUNDARY AND MAMMALIAN CORRELATION

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ABSTRACT

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It is suggested that there has been great confusion in the application of the terms " Pleistocene " and " Quaternary " both in geological and in palaeontological literature and that a definition which suits the geologist does not suit the palaeontologist. The best geological boundary (as adopted recently by Zeuner) seems to be the commencement of the first generally observable glaciation and this boundary may offer the best prospect of world-wide correlation on a basis of changing sea levels or changing climates. This does not coincide with any marked change in faunas comparable with Haug's boundary marked by the first appearance of the genera *Elephas*, *Equus* and *Bos* which, though not everywhere simultaneous, is generally regarded as marking the Villafranchian stage. Some authorities have, in the past, used the glacial boundary and their " Lower Pleistocene Fauna " is thus post-Villafranchian whereas another authority, accepting Haug's base, calls Villafranchian " Lower Pleistocene." It seems that any attempt to use the term " Pleistocene " in a faunal sense is bound to result only in further confusion and this is especially true when applied to Africa. The solution seems to lie in the deliberate abandonment of the term Pleistocene to its proper place as a stratigraphic term and the adoption of distinctive stage names for purposes of faunal correlation. It is then of no consequence how the geologist shifts the stratigraphic boundary or how the palaeontologist juggles with faunal limits to his stages as it is no longer essential that the boundaries should be identical on the two definitions. Suggested names for the post-Villafranchian stages are *Adolesican* and *Novian;* and then Early, Middle and Late Adolescian faunas would be roughly equivalent to Zeuner's (glacial) Lower, Middle and Upper Pleistocene, and Novian approximately Holocene.

LE CONDIZIONI GEOLOGICHE DELLA LIBIA FRA IL PLIOCENE ED IL QUATERNARIO

Per ARDITO DESIO
Italy

RÉSUMÉ

Les conditions de la Libye pendant le Pliocène et le Quaternaire peuvent être regardées de deux points de vue: stratigraphique et géomorphologique.

La presence de dépôts du Pliocène marin est encore douteuse. Les dépôts quaternaires marins connus jusq'aujourd'hui sont pour la plus grand partie du Tyrrhenienne. Tous le deux se trouvent dans une règion prochaine à la Mediterranée.

Parmi les dépôts continentaux, ceux de Sahabi en Syrtique, avec mammifères, ont particulière importance pour la détermination des dépôts continentaux de l'arrière pays.

Pour ce qui concerne la géomorphologie, nous connaissons que la Syrtique et particulièrement la région de Sahabi est une zone de dépression qui pour longtemps est resté ouverte vers la mer, lorsque en Cyrenaique et en Tripolitaine les communications avec la mer étaient fermées par le soulèvement des deux Gebels.

La presente relazione non ha la pretesa di annunciare fatti nuovi relativamente al problema delle condizioni geologiche della Libia fra il Pliocene ed il Quaternario, ma soltanto di riassumere brevemente lo stato attuale delle nostre conoscenze al riguardo. Va detto subito, intanto, che tale problema non è stato finora mai impostato, per cui le notizie che si posseggono hanno carattere frammentario ed occasionale. Giova pure aggiungere che l'attività geologica sul terreno è stata dedicata—negli anni che precedettero la recente guerra mondiale—quasi esclusivamente a scopi pratici (ricerche geominerarie e geoidrologiche) e che anche quelli fra i dati ed i materiali raccolti in tale occasione che potrebbero essere utili a chiarire il nostro problema sono stati per il momento messi in disparte come meno interessanti per le ricerche suddette.

Gli elementi principali su cui può essere fondata la ricostruzione delle condizioni geologiche della Libia al passaggio fra il Pliocene ed il Quaternario sono essenzialmente due, quelli stratigrafici e quelli morfologici. Esaminiamo ciò che di concreto si conosce intorno ad essi.

Dal punto di vista stratigrafico dobbiamo distinguere subito i terreni a facies marina da quelli a facies continentale per definire almeno i limiti fra i due ambienti.

Mancano fino ad oggi documenti sicuri che attestino l'esistenza nella Libia settentrionale di depositi pliocenici marini, ma mancano anche prove che ne escludano la presenza.

Le uniche segnalazioni dubitative sono rimaste ancora quelle da me fornite nel 1932 e nel 1935 (Desio, 1932; 1935, pp. 137—144). Si tratta di tre località, situate tutte tre nel retroterra della più profonda insenatura del Golfo della Gran Sirte, sino ad un'ottantina di chilometri dalla costa attuale. Gli elementi stratigrafico-paleontologici sono, in realtà, molto dubbi. Pochi esemplari di un'*Ostrea*, che rassomiglia al'*O. cucullata* Born., forma del Pliocene egiziano; due esemplari, di cui uno mal conservato, di una varietà nuova (o mutazione?) del *Clypeaster aegyptiacus* Mich. (*syrticus* Desio), specie caratteristica del Pliocene egiziano. Non conosco di persona la località in cui fu raccolto l'esemplare, perfettamente conservato, di *Clypeaster* dell'Uadi Melah. Quella d'origine dell'altro esemplare (Ain el-Braghi)—ch'è stata da me visitata di sfuggita in condizioni di sicurezza sfavorevoli—non si presta a ricerche stratigrafiche. Meno sfavorevoli sono tali condizioni sul Gebel el-Esc ove, però, la scarsità dei fossili mi ha impedito di raccogliere elementi probatori, tanto più che al momento dell'unica visita, non avevo elementi per pensare che potesse trattarsi di Pliocene, essendo tutto quel territorio completamente inesplorato.

Dal punto di vista stratigrafico più generale si può dire che il livello a *Clypeaster* se non appartiene al Pliocene, fa parte dei livelli più alti del Miocene, caratterizzati da grande diffusione dei gessi, mentre

il livello ad *Ostrea* se non è Pliocenico è indubbiamente Quaternario, poichè è sovrapposto alla serie miocenica. Soltanto ulteriori ricerche in luogo potranno meglio chiarire il problema. In ogni caso mancano in tutto il resto della Libia altre segnalazioni della " possibile " presenza del Pliocene marino, ma bisogna riconoscere che rimangono da esplorare ancora zone troppo vaste, specialmente nella Sirtica settentrionale, perchè si possa fin d'ora escludere definitivamente la sua esistenza. Le ricerche dovrebbero essere rivolte soprattutto al retroterra del segmento costiero compreso fra Nufilia ed Agedabia, ossia in corrispondenza della più profonda intaccatura dell'arco costiero della Gran Sirte ove più a lungo si è mantenuto il regime marittimo nel Neogene.

Anche le indagini eseguite nel sottosuolo della Tripolitania settentrionale, per le ricerche idrologiche e petrolifere, non hanno rivelato finora l'esistenza di orizzonti marini più recenti del Miocene, ma è ancora in corso l'esame micropaleontologico dei numerosi campioni raccolti nei livelli più elevati della serie.

Se ci riferiamo ora al Quaternario marino, i livelli più antichi fino ad oggi segnalati sarebbero quelli cirenaici riferiti da Stefanini al Siciliano (Stefanini, 1923), ma probabilmente di età più recente (Tirreniano), come quelli di buona parte della Libia costiera (Desio, 1935, vol. I). I giacimenti altimetricamente più elevati attribuiti al Tirreniano finora noti sono quelli di Agedabia con 36 m. s.l.m. Per quello che sino ad oggi si sa, il substrato del Terreniano è composto da terreni miocenici o ancora più antichi. Se può dunque rimanere qualche dubbio che la cimosa continentale del golfo della Gran Sirte sia stata per breve tratto sommersa durante il Pliocene, appare quasi certo che tutto il resto della Libia è rimasto durante quell'epoca in regime continentale.

In tali condizioni, è da prevedere che nel territorio libico mentre alcune zone erano soggette ad erosione, in altre si dovevano depositare i prodotti dell'erosione stessa. Le tracce di questi processi dovrebbero essere identificabili in parte nella stratigrafia, in parte nella morfologia.

I depositi continentali postmiocenici conosciuti sino ad oggi sembrano offrire scarsi elementi di giudizio dal punto di vista cronologico. Le faune a molluschi terrestri e lacustri finora note sono molto povere e sono state riferite concordemente al Quaternario.

In altra occasione (Desio, 1935, vol. I) ho attribuito al Neogene buona parte del sottile strato di ghiaie miste a sabbie che compongono i serir di origine alloctona (Desio, 1938) del retroterra libico. Le possibilità di una loro esatta datazione sono realmente scarse, ma qualche elemento si trova in Sirtica, ove ricoprono i terreni calcarei marini del Langhiano e dell'Elveziano. Non ho potuto notare in quella regione sovrapposizione di ghiaie quarzose di serir ai calcari ad *Alveolina bradyi* Silv., che rappresentano il Tortoniano, nè sovrapposizione di terreni di qualsiasi genere—salvo sabbie eoliche—ai depositi ghiaiosi di serir. Si deve quindi attribuire ad essi un'età postelveziana.

L'area di diffusione più settentrionale delle ghiaie suddette si trova nel territorio di Sahabi, ove sono stati raccolti numerosi resti di vertebrati fossili. Si tratta di una fauna, per ora soltanto in piccola parte studiata (Petrocchi, 1943) e composta da animali marini (pesci, cetacei), da animali anfibi (coccodrilli, ippopotami), da animali terrestri (proboscidati, rinoceronti, bovidi, equidi ecc.) associati apparentemente nel medesimo giacimento.

La fauna marina, di cui fanno parte anche molluschi, è stata concordemente attribuita al Miocene inferiore (D'Erasmo, 1934; Desio, 1935, vol. I; Stefanini, 1934).

Con tale determinazione non sembrano in armonia le specie di vertebrati continentali che, secondo le conclusioni—da ritenersi, tuttavia, ancora provvisorie—di uno studio paleontologico (Petrocchi, 1943), rappresenterebbero tipi d'età più recente e presumibilmente pliocenica. Va pure ricordato che mentre i vertebrati marini sono contenuti entro strati argillosi alternanti con livelli calcarei, quelli continentali (terrestri e d'acqua dolce) provengono da depositi sabbioso-ghiaiosi che sembrano riempire cavità d'erosione, incise nella serie marina calcareo-argillosa gessifera di tipo lagunare.

In ogni caso la fauna continentale di Sahabi rappresenta un elemento decisivo nella determinazione dell'età delle ghiaie alluvionali in cui la fauna stessa è contenuta e di molti altri depositi ghiaiosi che ricoprono i terreni morenici del Miocene.

Come ho già avuto occasione di affermare in passato (Desio, 1935, vol. I; 1938), penso che la deposizione delle ghiaie di serir, che in generale hanno potenza molto piccola, abbia avuto inizio, almeno in Sirtica, nel Miocene superiore e sia continuata per tutto il Pliocene e forse anche nel Quaternario inferiore. Per meglio dire, i processi di sedimentazione delle ghiaie ed i loro successivi rimaneggiamenti per opera di acque correnti si sarebbero ripetuti in quel tempo.

Depositi ghiaiosi di serir (alloctono) esistono anche in altre parti della Libia e non avrei motivi particolari per pensare che si tratti in generale di cosa diversa da quelli precedenti. Ma ritengo che anche le sabbie dei grandi ergh del Sahara Libico rappresentino in buona parte i sedimenti più sottili di una medesima formazione, d'origine prevalentemente alluvionale, rimaneggiati più tardi dal vento (Desio, 1935, vol I; 1938), per cui anche quelle notevoli masse di sabbia sarebbero in complesso della medesima età. I resti fossili raccolti qua e là nelle sabbie non hanno valore in quanto si tratta di fossili rimaneggiati. Devo tuttavia ricordare che in due località molto lontane (a S di Giarabub e presso la Garet el-Esc,* ho trovato frammenti di uova di *Psammornis* appartenenti ad una specie nuova (*P. libycus* Molt.) attribuibile probabilmente al Quaternario (Desio, 1935, vol. I).

Questi depositi ghiaioso-sabbiosi d'origine alluvionale sono limitati all'area sahariana del territorio libico ed è soltanto nella regione di Sahabi che si ravvicinano sensibilmente all'attuale costa mediterranea sovrapponendosi ai terreni marini del Miocene.

D'altra parte, la zona di maggior prominenza verso nord delle formazioni ghiaioso-sabbiose di serir coincide con l'area in cui il sollevamento marginale della regione libica mediterranea ha raggiunto complessivamente il valore minimo. Verso levante, infatti, sorgono il Gebel Cirenaico, verso ponente i tavolati della Sirtica e più oltre il Gebel Tripolitano. Le condizioni geomorfologiche dalla fine del Miocene al Quaternario erano, dunque, diverse nell'area della depressione tettonica del Golfo Neosirtico (Desio, 1942) verso il quale la regione sahariana si spingeva verso nord con una più rapida transizione morfologica che nelle aree laterali, assai più sollevate, le quali precludevano le comunicazioni dirette fra i bacini interni sahariani ed il bacino mediterraneo.

La fisionomia morfologica della Libia fra lo scorcio del Miocene e l'inizio Quaternario—di cui per ora conosciamo le linee generali (Desio, 1937; 1938)—sembra sia stata caratterizzata dalle ultime conseguenze delle deformazioni orogeniche provocate dai movimenti alpini sul margine meridionale della Tetide. Fra queste vanno messe anche le variazioni nella posizione della linea di costa ed i riflessi d'orgine climatica nel retroterra. Con la fine del Miocene, per esempio, il mare si è ritirato verso il nord per cui è presumibile che con l'inizio del Pliocene il clima del Deserto Libico abbia subito un sensibile inaridimento. D'altra parte all'inizio del Quaternario è subentrato in Libia un nuovo regime climatico, il quale ha fatto risentire la sua influenza, sia pure in forma via via più attenuata, sino all'estremo sud.

Se ora vogliamo dare un rapido sguardo alle principali vicende d'origine geomorfologica, sappiamo che nel Neogene i corsi d'acqua che nel Sahara Libico orientale discendevano dal sud verso il Golfo Neosirtico e che avevano formato il Serir di Calanscio andavano convergendo, via via che il territorio cirenaico sorgeva dalle acque del mare, verso l'arco più interno dell'attuale golfo della Gran Sirte ove era rimasto aperto un varco verso il Mediterraneo.

Nel Sahara Libico occidentale i bacini delle Edeien di Ubari e di Murzuch, bagnati da corsi d'acqua meno attivi, discendenti da ovest e tributari del Golfo Paleosirtico, come pure quelli del versante settentrionale del Tibesti che avevano sparso le loro alluvioni sul Serir Tibesti, erano stati, invece, assai prima isolati da ogni comunicazione col mare in conseguenza del sollevamento della regione dell'Harug' ed ora erano in fase di rimaneggiamento da parte degli agenti atmosferici e di una ridottissima attività di corsi d'acqua locali. Specchi d'acqua residuali caratterizzavano le aree di convergenza degli impluvi ove si deponevano sedimenti più sottili, limosi e calcarei (Calcari di Murzuch?)

Nel nord, i gebel Tripolitano e Cirenaico—con le loro propaggini marmarica e sirtica—che avevano separato i bacini sahariani dal bacino mediterraneo lasciando aperto il solo varco di Sahabi, erano

* Quest'ultima si trova presso la località con *Ostrea* cf. *cucullata* di cui è stato detto poco fa.

soggetti ad un'attiva fase d'erosione normale che accompagnava il loro graduale sollevamento. Durante questo lungo periodo di tempo più cicli d'erosione si sono succeduti nel territorio libico e non è sempre facile, allo stato attuale delle nostre conoscenze, sincronizzare i vari resti di antiche superfici topografiche legati a tali cicli in una regione tanto vasta la quale è stata soggetta nelle sue parti a vicende geologiche abbastanza diverse.

Se ci riferiamo per un momento al territorio dell'Harug' possiamo identificare molto bene tre sistemi relativamente recenti di superfici topografiche. Uno sepolto dalle lave basaltiche più antiche, che risale almeno all'Oligocene (Desio, 1938); uno formato dalla superficie di queste ultime manifestamente modellata dall'erosione normale (fluviale) ed uno più recente (quaternario) rappresentato dai solchi fluviali e torrentizi che incidono la superficie d'erosione dei basalti nei quali sono in parte dilagate le lave delle eruzioni più recenti.

Con questi tre sistemi sono raccordabili vari resti di antiche superfici topografiche del territorio libico. Il sistema, che possiamo chiamare quaternario, ma che in realtà comprende più di un ciclo d'erosione, è caratterizzato da una morfologia giovanile, il sistema neogenico da una morfologia matura. Soltanto il più recente si è potuto sviluppare e conservare nei territori che sono stati soggetti alla trasgressione miocenica (Desio, 1938).

In questo quadro morfologico vanno pure poste le manifestazioni vulcaniche (basaltiche) che con fasi alterne di parossismi e di quiete hanno ricoperto di lave soprattutto le regioni del Gebel es-Soda, dell'Harug' e del Tibesti nord-occidentale, provocando uno scompiglio nell'idrologia e nella morfologia locali. Dei due periodi di più intensa attività eruttiva sembra che uno sia anteriore, l'altro posteriore al Pliocene.

Questa ricostruzione a grandi linee delle più salienti vicende geologiche del territorio libico fra il termine del Miocene e l'inizio del Quaternario rappresenta soltanto un tentativo di sintesi geomorfologica che possa servire come ipotesi di lavoro. Le indagini stratigrafiche e geomorfologiche relative all'epoca pliocenica ed al Quaternario libico sono—come ho detto da principio—ancora molto scarse ed uno studio razionale non è stato ancora nemmeno impostato. Lo stesso coordinamento degli scarsi dati frammentari ed eterogenei sino ad oggi disponibili non consente di ricavare buone conclusioni.

Per chiudere questa rapida sintesi vorrei segnalare ai futuri ricercatori la Sirtica orientale come la regione che più di qualsiasi altra sembra prestarsi per indagini stratigrafiche sul Pliocene e sul Quaternario della Libia. Di là conviene partire per impostare razionalmente lo studio sistematico su tutto il territorio libico, tenendo conto però ch'esso è sufficientemente vasto e vario da presentare condizioni geologiche abbastanza diverse nelle sue varie parti.

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EDAD DE LAS TERRAZAS MARINAS DE LA PATAGONIA

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ABSTRACT

Los estudios efectuados por el autor en 1927–1933 sobre las terrazas marinas de la Patagonia, y ampliados entre 1935 y 1946, han permitido establecer con satisfactoria exactitud la secuencia de los varios niveles, basada en su posición altimétrica y en la composición de sus faunas de Moluscos.

En términos generales, a lo largo de la costa atlántica de la Patagonia se reconocen seis niveles principales de terrazas marinas, la mayoría de los cuales se pueden seguir en una extensión de varios grados de latitud. La región más favorable para el estudio de estas terrazas es la de Puerto Deseado (47–48° lat.), donde hay cinco niveles distintos, que se pueden correlacionar exàctamente con las terrazas fluviales escalonadas a lo largo del río.

Los seis niveles mencionados se encuentran, respectivamente, a 170–186 m. sobre nivel del mar; a 115–140; a 45–95; entre 15 y 42; a 15-30, y a 8–12. El primero y más elevado se interna hasta 50-55 km. de la costa y encierra una fauna de Moluscos con un 40-50% de especies extinguidas: su edad es probablemente del Plioceno superior. El segundo nivel tiene una fauna muy parecida al precedente. El tercero y el cuarto, referidos respectivamente a la penúltima y la última fase interglacial, comprenden especies casi todas vivientes, pero hoy en día retiradas en parte más al Norte, o sea, en aguas más cálidas. En cambio, el quinto nivel se caracteriza por la presencia de numerosas especies actualmente confinadas en el distrito fueguino-magallánico, pudiéndose homologar con la última fase glacial, o el Posglacial inferior; en tanto que el último nivel (a veces en dos series principales) comprende especies que habitan todas el mar adyacente.

LAS primeras referencias sobre las terrazas marinas de la Patagonia se encuentran en Darwin (1846), quien a lo largo de la costa atlántica reconoció varios niveles escalonados desde la playa actual hasta alturas de cerca de 300 m. En realidad, dichos niveles o escalones no se deben todos a la erosión del océano, sino que en gran parte corresponden a terrazas continentales, o se relacionan con la presencia de horizontes y bancos resistentes en los terrenos relativameate blandos del Cretáceo y Terciario, dispuestos en capas más o menos horizontales.

A partir de 1895 y hasta 1903, Carlos Ameghino descubrió en la zona costanera situada entre Comodoro Rivadavia y San Julián, y en particular cerca de Puerto Deseado, varios restos de antiguas playas marinas, con fósiles (especialmente Moluscos) bien conservados, que pertenecen por lo menos a tres distintos niveles de terrazas. Los fósiles fueron determinados por Ihering (1907), quien, junto con Florentino Ameghino, situó los yacimientos más antiguos en el llamado " Araucanense marino," al cual atribuía una edad pliocénica, y los más recientes en el Pampense, refiriéndolos al Plistoceno; Florentino Ameghino (1906) los repartía entre el Mioceno superior y el Plistoceno.

En esos mismos años (1896) J. B. Hatcher descubría las terrazas marinas del Cabo Buentiempo o Fairweather (Río Gallegos) y de la Estancia Darwin (San Julián), cuyos fósiles fueron determinados por Pilsbry y Ortmann (1902), quienes las atribuyeron al Plioceno.

Entre 1927 y principios de 1932, mientras atendía al levantamiento geológico de la región del Golfo de San Jorge, tuve oportunidad de realizar un detenido estudio de las terrazas marinas de ese trecho de costa y de extender mis observaciones hacia el Norte hasta el Golfo de San Matías, y hacia el Sur hasta San Julián, descubriendo y explorando un crecido número de yacimientos fosilíferos nuevos, además de visitar la mayor parte de los ya conocidos. Los resultados de estos trabajos, completados oportunamente por la determinación de los fósiles por mí coleccionados, están consignados en una monografía que apareció al año siguiente (Feruglio, 1933).

Posteriormente, entre abril de 1934 y mediados de 1937, pude efectuar una nueva serie de observaciones en la zona costanera entre Comodoro Rivadavia y Río Gallegos, recolectando nuevo material de estudio; observaciones que tuve oportunidad de ampliar y completar a principios de 1946 y del año en curso. El conjunto de estos trabajos importa una revisión casi completa de las terrazas de la zona costanera, desde el Norte de la Patagonia hasta al Estrecho de Magallanes.

Los yacimientos actualmente reconocidos y explorados suman, en total, cerca de 50, distribuyéndose desde San Antonio Oeste (41° lat.) hasta la desembocadura del Río Gallegos (51° 35′ lat.). La costa atlántica que se extiende entre Río Gallegos y Río Grande, en Tierra del Fuego, está bordeada en gran parte por depósitos glaciales y fluvioglaciales abandonados por el manto de hielo que descendía de las montañas situadas a ambos lados del Estrecho de Magallanes, el cual ha borrado todo rastro de las terrazas marinas anteriores a la última glaciación. Del mismo modo, a lo largo de la costa pacífica (en realidad, muy poco explorada hasta ahora), la intensa erosión glacial ha destruído, al parecer, casi todo vestigio de las antiguas playas levantadas.

La costa atlántica de Patagonia y Tierra del Fuego se levanta las más de las veces en forma de acantilados, con alturas que desde menos de 10 m. llegan hasta 150. En algunos trechos, sin embargo, la escarpa costanera retrocede tierra adentro, en una extensión que varía entre pocos centenares de metros y algunos kilómetros, dejando lugar a planicies cubiertas de depósitos de playa, ora en forma de terrazas, ora de cordones litorales bien marcados y en ocasiones en número de tres o más. Tanto las terrazas como los cordones se componen de arena, grava y cascajo de rocas especialmente porfíricas y encierran a menudo abundantes restos fósiles marinos, sobre todo conchas de Moluscos y *Balanus*; a veces también Braquiópodos, Equínidos, Briozoos, etc. En los depósitos más recientes, los sedimentos son por lo general completamente sueltos, mientras que en los más antiguos ellos se presentan en parte cementados por carbonato de calcio.

La mayoría de las playas levantadas de la Patagonia se encuentran precisamente en estas antiguas bahías hoy rellenadas, a alturas comprendidas entre 5 y 45 m. sobre el nivel del mar. En algunas partes, sin embargo, los depósitos de playa marina aparecen también encima de la meseta costanera, formando un manto relativamente delgado sobre los terrenos más antiguos, tanto terciarios como preterciarios, a una altitud de 50 hasto casi 200 m. En la saliente de Puerto Deseado (47° 45′ lat.), donde estas terrazas alcanzan su mayor altura y se presentan más desarolladas, la superior se interna hasta 50–55 km. de la costa.

Atendiendo a su posición altimétrica y a la composición de sus faunas, especialmente de Moluscos, los yacimientos explorados se pueden agrupar en seis sistemas o niveles principales; sistemas que he designado con números romanos y, al mismo tiempo (para evitar posibles confusiones en el futuro), también con el nombre de las localidades típicas. En efecto, algunos sistemas abarcan varios yacimientos más o menos distantes entre sí y que probablemente no son todos estríctamente contemporáneos. Así, las terrazas más elevadas, reunidas en los tres primeros sistemas, no ocupan grandes extensiones, presentándose tan sólo en puntos aislados, o en trechos relativamente reducidos y, por lo general, en las salientes más pronunciadas de la costa; al paso que los niveles más bajos, sobre todo los últimos dos, se pueden seguir a lo largo de varios grados de latitud.

La serie más completa de terrazas marinas se encuentra en la saliente de Puerto Descado, donde se observan cinco niveles o escalones bien distintos, con fósiles a veces abundantes, bien conservados y característicos; niveles que se escalonan entre 8–10 m. y 186 m. Además, a 74–80 m. se encuentra un escalón intermedio (Terraza del Cerro Alonso), esculpido en las rocas porfíricas jurásicas, que muy probablemente ha sido también labrado por la erosión marina, pero que posteriormente fué cubierto por los aluviones del Río Deseado; siendo posible que, debajo del manto aluvional, en parte cementado en conglomerado, se encuentren remanentes de los antiguos depósitos de playa.

La serie así establecida es quizás una de las más completas que se conocen actualmente en la Tierra. Los seis sistemas que la componen son los siguientes, a partir del más elevado y antiguo.*

I. TERRAZAS DEL CABO BUENTIEMPO Y DEL CERRO LACIAR

La terraza del Cabo Buentiempo, o Fairweather, ocupa el borde de la meseta costanera que se levanta inmediatamente al Norte de la desembocandura del Río Gallegos (51° 32′ lat.), a una ultura

* Una descripción detallada de todas estas terrazas se encuentra en mi memoria, actualmente en publicación, titulada *Descripción geológica de la Patagonia*, en 3 tomos: Dirección General de Yacimientos Petrolíferos Fiscales, Buenos Aires, Diagonal Norte, 777.

de 131–138 m. El depósito marino consiste en un manto de arena, en parte ferruginosa, grava y cascajo parcialmente cementados en conglomerado, dispuesto en discordancia marcadísima sobre la serie continental del Santacrucense (Mioceno), que constituye el cuerpo de la meseta, y recubierto, a su vez, por aluviones. El depósito marino encierra abundantes restos de Moluscos y *Balanus*, que pertenecen a quince especies distintas, de las cuales la mitad son extinguidas y relacionadas en parte con formas del Terciario medio (Patagoniense), como *Dosinia meridionalis*, *Ostrea faira*, *Pecten actinodes* y *Turritella patagonica innotabilis*.

La terraza del Cerro Laciar está situada 50–55 km. al WNW de Puerto Deseado (47°–35′ lat.) y ocupa la meseta más alta que se encuentra a lo largo del curso inferior del Río Deseado, a una altitud de 170–186 m. El cuerpo de la meseta está formado por sedimentos del Patagoniense inferior (Terciario medio), sobre los cuales yace un manto de arena y grava, parcialmente cementado en conglomerado, que encierra una multitud de Moluscos fósiles y restos de otros Invertebrados. Sobre un total de 40 especies identificadas hasta el presente, cerca de 16 son extinguidas, lo que da una proporción del 38–40%. Las especies en común con la terrazas del Cabo Buentiempo son, sin embargo, apenas 4, lo que puede explicarse por el número reducido de formas que encierra este ultimo yacimiento, además que por lo distancia que lo separa del del Cerro Laciar (4° de latitud).

En su conjunto, la fauna de la terraza del Cerro Laciar ocupa una posición intermedia entre la del Rionegrense (indudablemente terciaria) y las fauna actual, distinguiéndose de la primera por la aparición de un crecido número de especies aún vivientes. Las formas desaparecidas pertenecen a los géneros *Terebratella*, *Cardita*, *Chione*, *Amiantis*, *Pecten*, *Ostrea*, etc.

II. TERRAZA DE LA ESTANCIA CABO TRES PUNTAS (PUERTO DESEADO)

Ocupa el escalón situado inmediatamente debajo del del Cerro Laciar, a alturas comprendidas entre 100 y 140 sobre el nivel del mar. La extensa meseta de la Pampa Alta está cubierta por un manto espeso de aluviones, depositados, al parecer, durante la antepenúltima invasión glacial. Los sedimentos marinos afloran saltuariamente en los bordes de la terraza, debajo de los aluviones, y consisten en arena y grava con restos de Moluscos marinos y *Balanus*. Las especies identificadas hasta el presente no pasan de 12, siendo todas en común con el yacimiento del Cerro Laciar, incluso las formas desaparedicas (*Terebratella tehuelcha*, *Venericardia tehuelchana*, *Pecten actinodes*, *P. deseadensis* y *Ostrea ferrariisi*).

A este mismo sistema refiero también los yacimentos del Monte Espejo, Estancia Darwin y Cañadón de Santa Rosa (48° 40′ y 50°). Estos dos últimos yacimientos, a pesar se su baja posición altimétrica (los depósitos del Cañadón de Santa Rosa llegan hasta bajo del nivel del mar), se relacionan en un todo con los anteriores, siendo las especies extinguidas (*Terebratella tehuelcha*, *Pecten actinodes*, *P. deseadensis* y *Ostrea ferrariisi*), menos una forma nueva de *Limatula*, todas comunes con la terraza de la Estancia Cabo Tres Puntas.

III. TERRAZA DE CAMARONES

Esta terraza comprende tres solos yacimientos, situados el primero en Cabo Raso (44° 18′ lat.), entre 40 y 76 m. s.n.m., el segundo en Camarones (44° 42′ lat.), entre 40 y 55 m.; y el tercero en la Península del Cabo Dos Bahías (45° lat.), a 79–90 m. Los tres encierran casi las mismas especies de Moluscos, todas ellas vivientes, con excepción de una forma nueva de *Ostrea* (*O. tehuelche*), muy próxima de la viviente *O. puelchana*. Entre las demás especies son notables: *Pectunculus longior*, *Diplodonta vilardeboaena*, *Mactra isabelleana*, *Pitaria rostrata*, *Scala Orbignyi* y *Olivancillaria auricularia*, que hoy se encuentran a lo largo de la costa atlántica algunos grados de latitud más al Norte.

IV. TERRAZAS DEL ESCARPADO NORTE (PUERTO DESEADO) Y BAHÍA SANGUINETO, Y CORDÓN LITORAL CON " MACTRA ISABELLEANA " DE BAHÍA BUSTAMANTE

La terraza del Escarpado Norte aparece a ambos lados de la desembocadura del Río Deseado, entre 15 y 35 m. s.n.m. y encierra una fauna de Moluscos de especies casi todas vivientes, menos una

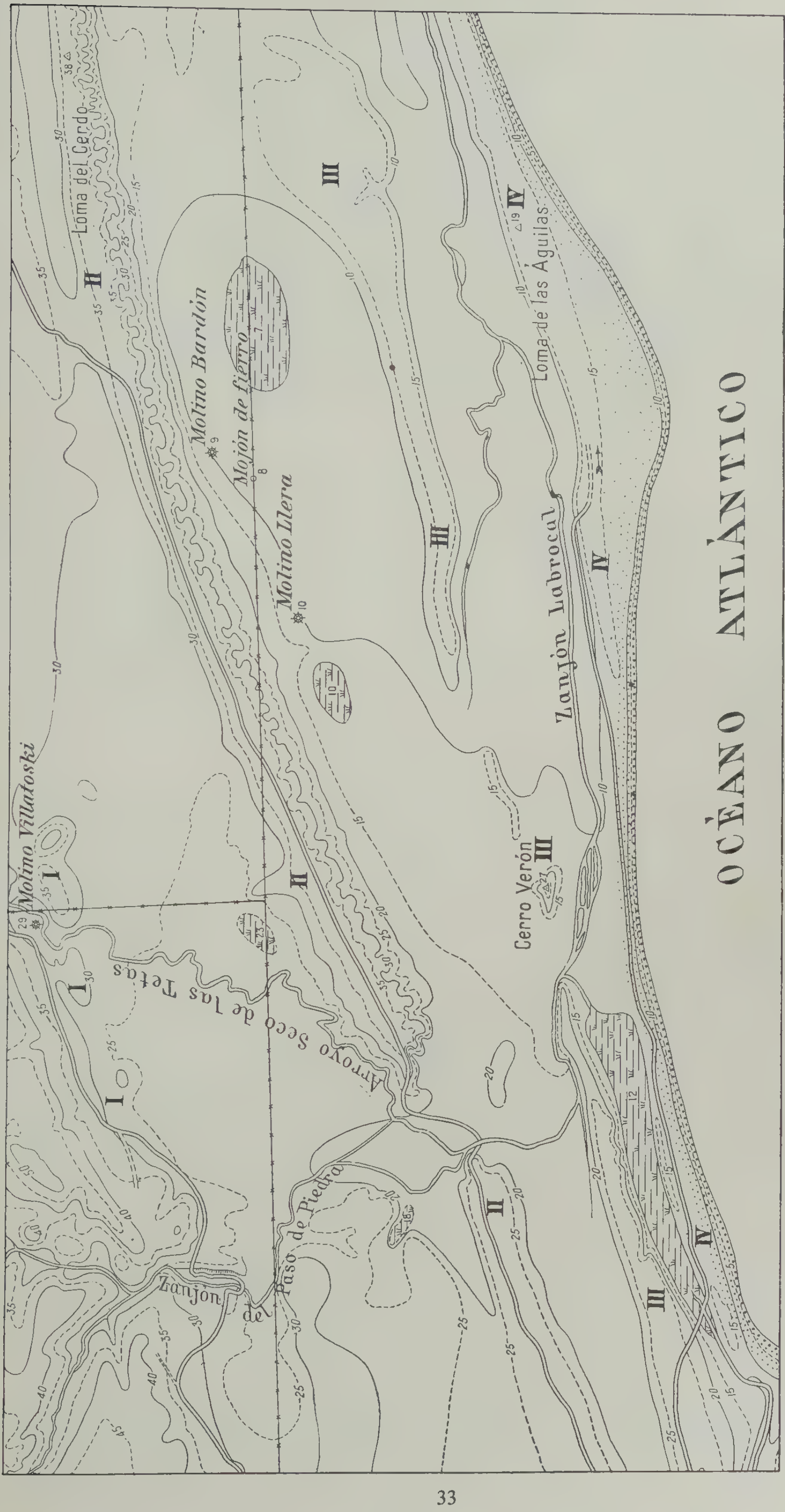

FIG. 1.—*Cordones litorales en la planicie situada al Oeste de Bahía Bustamante (Territorio de Chubut): el cordón marcado con I es el con* Mactra isabelleana; *el cordón III corresponde a la Terraza de Mazarredo.*

forma de *Ostrea*, afín y quizá idéntica de la *O. tehuelche*, del nivel anterior, pero que se distingue a primera vista de la fauna del nivel siguiente por la ausencia de especies de aguas frías. La terraza de Bahía Sanguineto comprende un horizonte marino, con restos de Moluscos de la fauna actual, pero algunos de ellos hoy retirados más al Norte (*Diplodonta patagonica*, *Nucula puelcha*, *Pitaria rostrata* y *Littorinida australis*) y un horizonte continental con huesos de Mamíferos extinguidos de la fauna pampense, que pertenecen a los géneros *Megatherium*, *Mylodon*, *Glyptodon*, *Scelidotherium*, etc. Este segundo horizonte está cubierto por un espeso manto de aluviones. La terraza alcanza una altura de 20–21 m. s.n.m. y ocupa una antigua bahía excavada en las capas patagonienses.

El cordón litoral con *Mactra isabelleana* se presenta en la parte más interna de la planicie costanera situada entre la Península del Cabo Dos Bahías y la Estancia Llera, al WSW de Bahía Bustamante. Este cordón litoral es el más interior de una serie de 3 o 4, distinguiéndose de los restantes no solamente por su altura (que está comprendida entre 25 y 42 m. s.n.m.), sino también por su disección mucha más profunda. Además, se caracteriza este cordón por la presencia en su fauna (compuesta exclusivamente de especies actuales) de algunas formas que hoy en día viven más al Norte, como ser: *Mactra isabelleana*, *M. patagonica* y *Pitaria rostrata*.

V. TERRAZA DE PUERTO MAZARREDO

Este nivel se ha podido seguir, a lo largo de la costa, desde la Bahía Vera, cerca de Cabo Raso (44° 10′ lat.), hasta San Julián (49° 20′ lat.), a alturas relativamente uniformes (entre 15 y 30 m.).

Se compone de depósitos en parte cementados por caliza, que encierran abundantes conchas de Moluscos, pertenecientes todas a especies actuales, entre las cuales, sin embargo, se destacan algunas actualmente retiradas en el distrito magallánico-fueguino, o sea, en aguas más frías, a saber: *Fissurella picta*, *F. oriens*, *Tegula atra*, *Nucella* (*Acanthina*) *calcar*, *Mangelia purissima* y *Loxechinus albus*. Esta asociación faunística, sumanente característica, resulta aún más significativa por su contraste con la del sistema siguiente.

VI. TERRAZA DE COMODORO RIVADAVIA

Comprende las terrazas y cordones litorales más exteriores y recientes, situados generalmente a alturas de 8 o 12 m., pero que en algunos puntos pueden llegar a 16 y, excepcionalmente, a 19 m. Los cordones son a veces en número de dos o tres. La fauna de este nivel se distingue por la desaparición de las formas de aguas frías antes mencionadas y por estar constituída por especies que, salvo quizá alguna excepción, viven todas en el mar adyacente. El cordón litoral inmediato a la playa actual llega a veces a confundirse con ésta.

Los estudios realizados hasta el presente han permitido establecer con satisfactoria exactitud la secuencia de las terrazas marinas de la Patagonia. Alguna duda podría aun caber con respecto a la posición de la terraza de Bahía Sanguineto, que algunos autores habían considerado posglacial, pero que, a mi juicio, es anterior a la última glaciación, tanto por los fósiles que encierra, como porque los horizontes fosilíferos que la componen están cubiertos por un espeso manto de aluviones groseros, que evidencian un largo período de arrastre aluvional, conexo con una fase glaciopluvial. Igual duda podría adelantarse respecto al cordón litoral con *Mactra isabelleana* de Bahía Bustamante, para el cual cabría la posibilidad (a mi parecer, poco probable) de que corresponda al sistema de Puerto Mazarredo.

Aparte estas cuestiones, el problema más importante que se plantea es el relativo a la edad de las terrazas en estudio. Para su dilucidación se pueden seguir dos caminos diferentes: 1°, el estudio de las faunas de Moluscos; 2°, el de las relaciones de las terrazas marinas con las terrazas aluvionales escalonadas a lo largo de los ríos, especialmente el Deseado, y de éstas con los depósitos glaciales que se extienden al pie de la Cordillera.

En cuanto al primer punto, cabe ante todo destacar el marcado contraste que existe entre las faunas de los yacimientos adscriptos a los sistemas I y II y las de los niveles infrastantes. En los primeros, en efecto, la proporción de las especies extinguidas es relativamente elevada, alcanzando

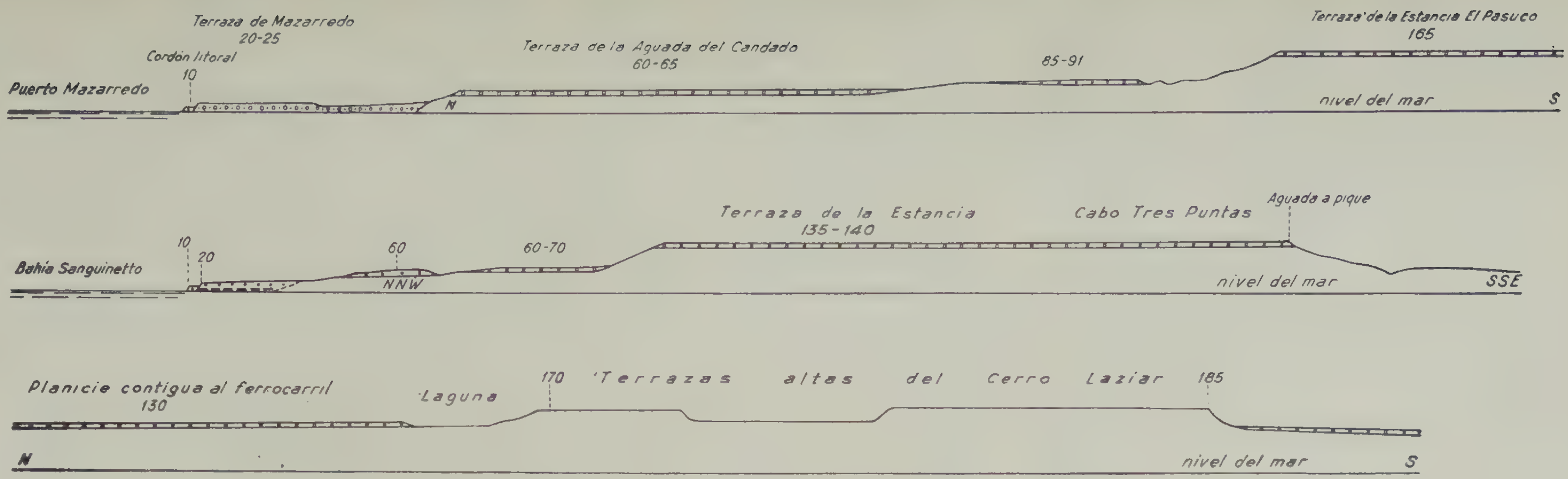

FIG. 2.—*Perfiles de las terrazas de las región de Puerto Deseado.*

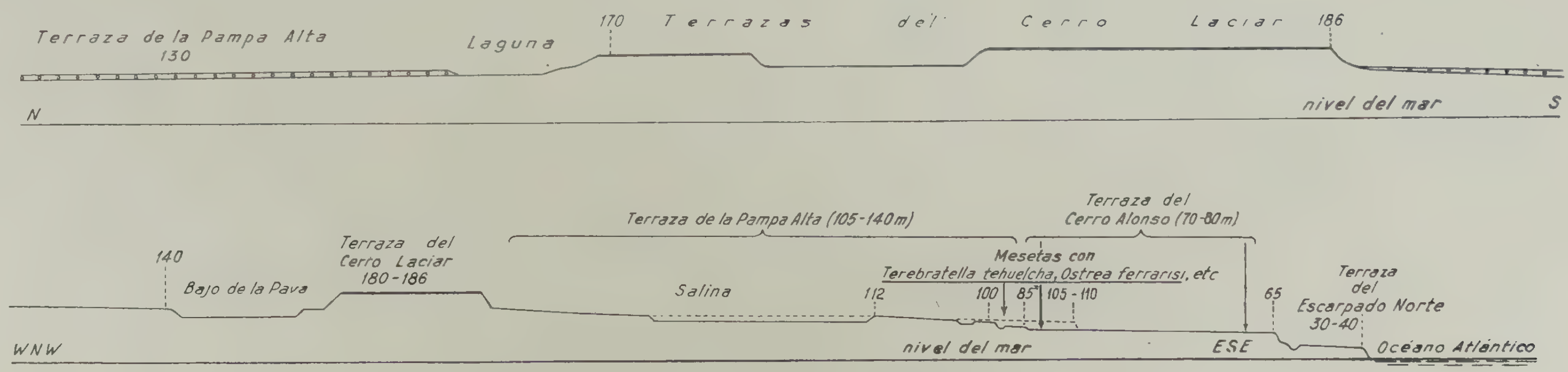

FIG. 3.—*Perfil de las terrazas de Puerto Deseado.*

el 50% en el yacimiento del Cabo Buentiempo y aproximadamente el 40% en el del Cerro Laciar. En el primero el número de las especies identificadas es de apenas 15; pero en el segundo llega a 40, lo que ofrece una base satisfactoria para sentar conclusiones atendibles. En el sistema II, la proporción de las formas desaparecidas varía según los yacimientos; en el del Cañadón de Santa Rosa, que es el más rico de especies, el porcentaje resulta del 35%. En términos generales, la fauna de este sistema aparece estrechamente vinculada con la del primero, aunque con una menor proporción de formas desaparecidas.

El número relativamente elevado de las especies extinguidas en las terrazas del Cabo Buentiempo y del Cerro Laciar no deja duda, a mi parecer, sobre su edad pliocénica antes que plistocénica; ocupando, como ya dije, esos yacimientos una posición intermedia, en cuanto a su fauna, entre el Rionegrense (indudablemente terciario, quizá del Plioceno inferior) y las terrazas del sistema III en adelante, las cuales encierran Moluscos que pertenecen a especies casi exclusivamente actuales.

Respecto al yacimiento del Cabo Buentiempo, corresponde, además, señalar que la terrazas sobre la cual se encuentra queda situada a muy corta distancia (menos de 20 km.) de las morenas más exteriores y antiguas abandonadas por el glaciar magallánico. Ahora bien: la composición de la fauna de dicha terraza revela condiciones de clima relativamente cálido, excluyendo en cualquier caso toda influencia de clima glacial. Así que también por este medio podemos concluir por referirla al Plioceno, antes que al Plistoceno.

El punto más dudoso es el relativo a la edad de las terrazas del sistema II. En el cuadro estratigráfico que agrego al final, este sistema fué colocado en el primer Interglacial. Esto se hizo teniendo en cuenta la posición altimétrica relativamente baja que ocupan algunos de sus yacimientos y, además, la circunstancia de que en la Pampa Alta, cerca de Puerto Deseado, los sedimentos de playa marina de este sistema están cubiertos directamente por los depósitos fluvioglaciales conexos con la antepenúltima glaciación. La solución definitiva de este problema está supeditada también al problema relativo al número de las expansiones glaciales. En Patagonia se conocen hasta ahora restos de dos distintas invasiones glaciales, de las cuales la más antigua fué también la más extensa; pero en la cuenca del Lago Nahuél Huapí existen indicios de la existencia de una tercera y más antigua glaciación, que estaría representada por las morenas más exteriores de Pilcaniyén.

El segundo grupo de terrazas, que comprende los sistemas III a VI, se caracteriza a primera vista por estar sus faunas constituídas exclusivamente por especies actuales, con la sola excepción de la terraza III (de Camarones), en la cual abunda una forma de *Ostrea* (*O. tehuelche*) hoy día desaparecida, si bien muy afín de la viviente *O. puelchana*. Por eso no cabe duda que estos sistemas pertenecen todos al Cuaternario.

El sistema VI se distingue, además que por su escasa altura (en general, entre 8 y 12 m.) y el aspecto completamente fresco de sus depósitos, también porque los Moluscos que en él se encuentran viven aún en el mar adyacente. El conjunto de estas circunstancias evidencia una edad muy reciente, sin duda posterior a las grandes oscilaciones climáticas del Plistoceno, motivo por el cual lo colocamos en el Posglacial superior.

En contraste con el sistema precedente, el sistema V (de Puerto Mazarredo) presenta como característica más notable la presencia de varias especies hoy día confinadas en la provincia fueguino-magallánica, la cual se prolonga hacia el Norte, a lo la largo de la corriente fría de las Malvinas o Falkland, hasta la latitud de la provincia de Buenos Aires. Los depósitos de esta terraza están en parte comentados por carbonato cálcico y alcanzan una altitud de hasta 25–30 m. Todo esto denota una edad más antigua y correspondiente, a mi parecer, a la última glaciación, o a los primeros tiempos del Posglacial. Efectivamente, en Puerto Deseado los depósitos de este sistema se recuestan a los sedimentos fluvioglaciales abandonados por el río antes de que quedara en seco al desobstruirse el valle del Río Baker (actual desagüe del Lago Buenos Aires), como consecuencia de la disipación del manto de hielo que cubría la Cordillera.

A su vez, los sedimentos marinos de la terraza del Escarpado Norte están cubiertos por un espeso manto de aluviones groseros, depositados por el Río Deseado durante la última expansión glacial.

FIG. 4.—*Mapa general de la Patagonia, con la indicación de las principales terrazas marinas. La línea gruesa al pie de la Cordillera de los Andes marca la extensión máxima del manto de hielo.*

Esta circunstancia y la ausencia de la característica asociación de Moluscos de aguas frías que se observa en la terraza inmediatamente infrastante, además de su mayor elevación, comprueban que su edad es anterior a la última glaciación, pudiéndose paralelizar con la última fase interglacial.

En cuanto al sistema III, o de Camarones, su característica esencial consiste en la presencia de varias especies hoy retiradas más al Norte, o sea, en aguas más cálidas. En mis primeras publicaciones yo habia paralelizado esta terraza con la anterior; conclusión que no se puede más sostener, atendiendo a su elevación mucho mayor (79–90 m. en la Península del Cabo Dos Bahías). En Puerto Deseado esta terraza está representada por el escalón del Cerro Alonso (74–80 m.), que está separado del del Escarpado Norte por un desnivel de 40–45 m. Por lo manifestado, estimo que este nivel debe de corresponder a la penúltima, antes que a la última fase interglacial.

Resumiendo: los resultados principales de los estudios que he realizado en los últimos veinte años, consisten en el descubrimiento de tres niveles de terrazas marinas que, por su contenido faunístico, evidencian la influencia de las grandes oscilaciones climáticas del Plistoceno; habiendo conseguido identificar dos distintas faunas interglaciales (correspondientes al penúltimo y último Interglacial) y una fauna conexa con la última glaciación, y una más precisa delimitación estratigráfica, faunística y cronológica de las demás terrazas, fundado en la exploración de un crecido número de nuevos yacimientos y en la determinación de sus fósiles; y en la correlación de esas mismas terrazas con las terrazas aluvionales escalonadas a lo largo de los ríos, especialmente el Deseado, y con los depósitos morénicos abandonados al pie de la Cordillera.

En el cuadro estratigráfico que acompaño, he tratado de fijar una correlación entre las terrazas marinas y aluvionales, y las fases glaciales e interglaciales, partiendo de la supuesta existencia de cuatro glaciaciones.

EDAD	TERRAZAS MARINAS	TERRAZAS ALUVIONALES
Posglacial	*Terraza de Comodoro Rivadavia:* (*b*) Cordones litorales contiguos a la playa actual, con fauna de Moluscos idéntica a la del mar adyacente: 6–12 m. (*a*) Cordones litorales a 1,000–1,500 m. de la costa, en Puerto Lobos, Bahía Solano y Rincón del Buque: 10–12 m.	Terrazas situadas hasta 15–20 m. sobre el fondo de los valles.
4ª Glaciación	*Terraza de Mazarredo:* depósitos de playa, en parte cementados, con fauna de Moluscos actuales, pero en parte de aguas frías: 15-30 m.	*Terrazas aluvionales de Puerto Deseado* (20–25 m.) y del *Escarpado Norte* (35-40 m.), y terrazas de Koluél-Kaike, a 12–65 m. sobre el Río Deseado.
3er Interglacial 3ª Glaciación	*Terrazas de Bahía Sanguineto y del Escarpado Norte* (30–35 m.) cerca de Río Deseado y Cordón litoral con *Mactra isabelleana* de Bahía Bustamante (30–42 m.)	*Terraza del Cerro Alonso* (Puerto Deseado), cubierta de aluviones en parte cementados: 74–80 m., y de la Angostura (Río Deseado) a 76–103 m. sobre el río.
2° Interglacial 2ª Glaciación	*Terraza de Camarones*, con fauna de Moluscos en parte de aguas cálidas y casi todas vivientes, menos *Ostrea tehuelche*: 79–90 m.	*Terraza de la Pampa Alta* (Puerto Deseado), a 105–140 m., Meseta Espinosa (Las Heras) y Valle Hermoso (Río Senguerr).
1er Interglacial 1ª Glaciación	*Terraza de la Estancia Cabo Tres Puntas* (Río Deseado), con fauna de Moluscos en parte extinguidos (hasta el 35%): 115-140 m.	*Terrazas de la Pampa María Santísima*, a 220–250 m. sobre el Río Senguerr y 300-330 m. sobre el Río Deseado.
Plioceno	*Terraza del Cerro Laciar* (Puerto Deseado), con fauna de Moluscos con un 40% de especies extinguidas: 170–186 m.	
	Terraza del Cabo Buentiempo o Fairweather: fauna de Moluscos con un 50% de especies extinguidas: 131–138 m.	*Terraza de la Pampa del Castillo*, a 400-450 m. sobre el Río Senguerr y hasta 700-800 m. sobre el Río Deseado.

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THE PALAEOBOTANICAL BOUNDARY PLIOCENE-PLEISTOCENE IN THE NETHERLANDS

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ABSTRACT

The youngest Tertiary flora known from the Netherlands has been found in the Reuverian Clay which is worked in pits east of the river Maas on either side of the Dutch-German frontier, near Reuver, Swalmen and Brunssum. This clay has yielded macroscopic remains of about one hundred genera of gymnosperms and angiosperms among which are especially noticeable *Actinidia*, *Brasenia*, *Carya*, *Cinnamomum*, *Dulichium*, *Epipremnum*, *Euryale*, *Liquidambar*, *Magnolia*, *Nyssa*, *Phellodendron*, *Pseudolarix*, *Pterocarya* and *Sequoia*.

During the Early Glaciation apparently many of them were exterminated in our country, for the oldest known Pleistocene flora, that of the Clay of Tegelen, a village about 10 km. northward of Reuver, has so far only produced seven of the mentioned genera, viz. *Actinidia*, *Brasenia*, *Dulichium*, *Euryale*, *Magnolia*, *Phellodendron* and *Pterocarya*.

The Reuverian and Teglian Clays are also distinguishable by means of pollen-analysis. The former is characterized by the presence of pollen-grains of the conifers *Sciadopitys*, *Sequoia* or *Cryptomeria* cf. *Taxodium* and *Tsuga*, and of the dicotyledons *Carya*, *Fagus*, *Liquidambar*, *Nyssa*, *Phellodendron* and *Pterocarya*; of these in the Clay of Tegelen merely *Tsuga*, *Carya*, *Phellodendron* and *Pterocarya* occur.

This difference proffers the possibility of drawing the limit between our Young-Pliocene and Old-Pleistocene terrestrial deposits, even when macroscopic plant-remains are scanty or absent.

THE clay-pits on either side of the Dutch-German frontier near Tegelen, Reuver and Swalmen (see Fig. 1) have yielded abundant plant-remains which, as regards the fruits and seeds, are known especially by the work of Clement Reid and Mrs. E. M. Reid (1915).

At first these authors placed the Flora of Reuver (including Swalmen) at the top of the Middle Pliocene and that of Tegelen in the Upper Pliocene, but afterwards Mrs. Reid suggested that the former might represent the vegetation of the Lower Pliocene (1921).

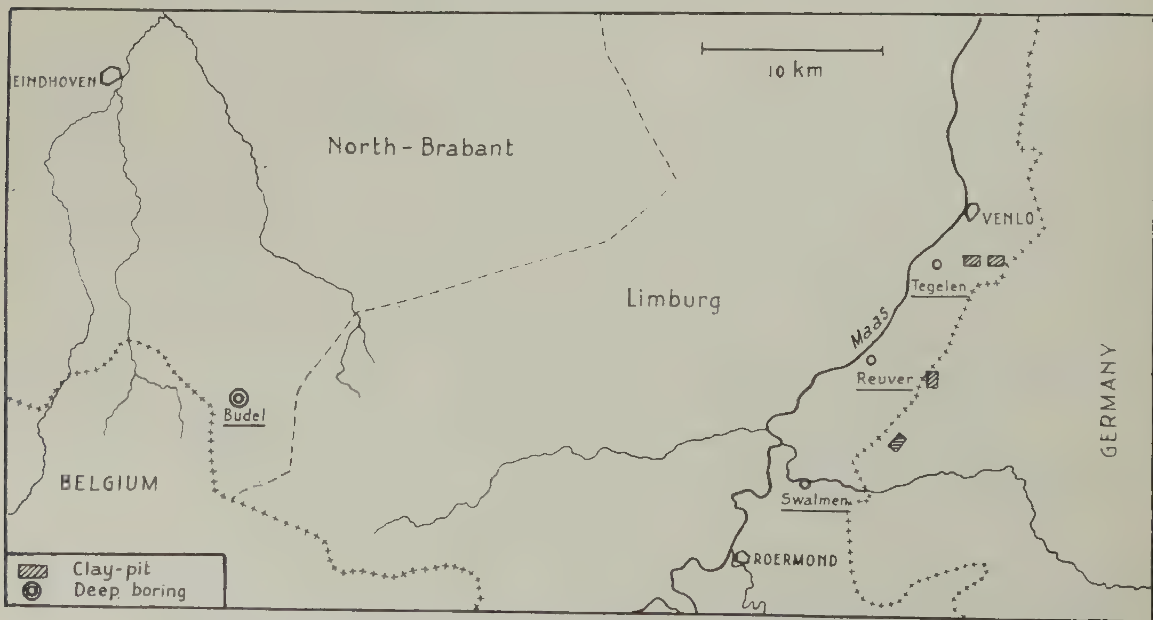

FIG. 1.—*Situation of the clay-pits and of the deep boring.*

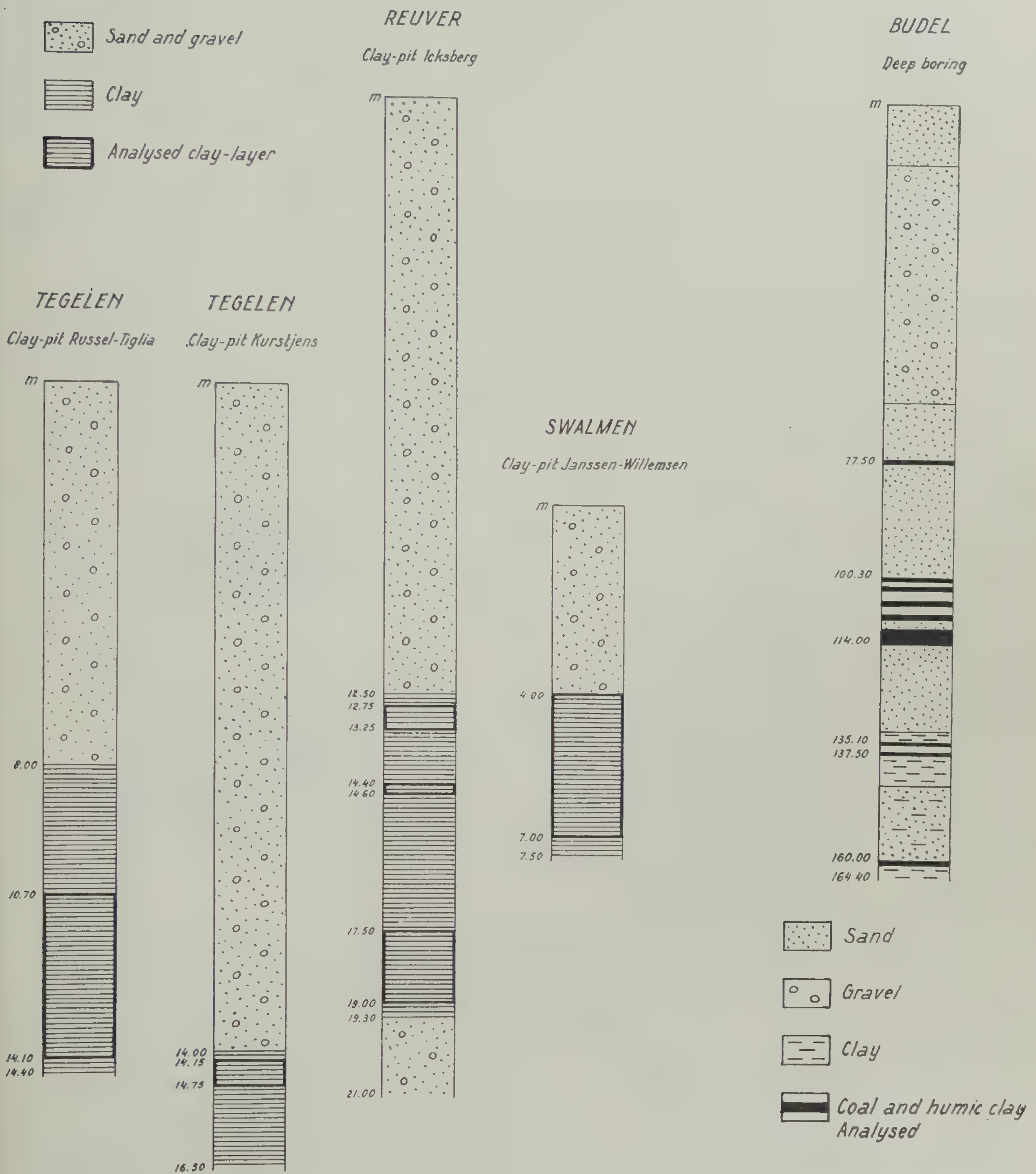

FIG. 2.—*Sections of the clay-pits and of the deep boring.*
The latter partly after J.I.S. Zonneveld (1947).

Unlike the Reuverian Clay, the Teglian Clay contains a lot of animal-remains. Among the molluscs *Viviparus glacialis* is the most conspicuous. The presence *inter alia* of shells of that gastropod enabled P. Tesch to recognize the Teglian horizon in the western part of our country. Here, for example in the region of Dordrecht, it overlies marine sediments with a " cold " fauna: *Yoldia arctica*, *Astarte borealis*, *Cardium groenlandicum* and other northern species. Tesch considers the arctic character of this fauna as indicating the first cold climatic phase and logically concludes that the Tegelen horizon belongs to the Pleistocene. In his opinion it corresponds to the Antepenultimate Interglacial (Tesch, 1934; 1937; 1946).

A. Schreuder (1945) judges the Teglian mammalian fauna as belonging to the Upper Villafranchian which she places in the Interstadial of the Early Glaciation. F. E. Zeuner (1945) separates the Teglian and Late Villafranchian faunas, the former dating to his mind likewise from the Interstadial Early Glaciation 1/II, whereas the latter might have immediately preceded that Glaciation.

So Tesch, Schreuder and Zeuner agree as to the Old-Pleistocene age of the Teglian Clay and we are of the same opinion. According to our view, the Teglian Flora is the oldest Pleistocene flora of the Netherlands. A comparison of that flora with the youngest Pliocene of this country, the Flora of Reuver, may reveal the influence of the Early Glaciation, in whole or in part, upon the vegetation of this area. It will allow us to indicate the palaeobotanical boundary Pliocene-Pleistocene.

The latest lists of Reuverian and Teglian plants, based on fruits and seeds, have been published by E. M. Reid and M. E. J. Chandler (1933) in their work on the London Clay Flora. Only those genera were listed the relationship of which they regarded as securely established.

Among the 95 Reuverian genera are 34 which at the present time are non-European: *Actinidia*, *Aralia*, *Ardisia*, *Brasenia*, *Bucklandia*, *Carya*, *Cinnamomum*, *Corylopsis*, *Decodon*, *Diospyros*, *Dulichium*, *Epipremnum*, *Eucommia*, *Euryale*, *Hakea*, *Hancea*, *Helwingia*, *Karwinskia*, *Liquidambar*, *Liriodendron*, *Maesa*, *Magnolia*, *Menispermum*, *Nelumbium*, *Nyssa*, *Orixa*, *Phellodendron*, *Proserpinaca*, *Pseudolarix*, *Pterocarya*, *Pyrularia*, *Sequoia*, *Stuartia* and *Zelkova*.

The Teglian list containing 66 genera, includes only 9 at the present time non-European, viz. *Actinidia*, *Decodon*, *Dulichium*, *Eucommia*, *Euryale*, *Magnolia*, *Menispermum*, *Phellodendron* and *Pterocarya*. To these can be added *Azolla* (Florschütz, 1938) and *Brasenia*.

Obviously the first Pleistocene climatic deterioration caused several genera to disappear from the scene.

This difference between the Reuverian and Teglian Floras enables us to discern whether a terrestrial sediment is Young-Pliocene or Old-Pleistocene, provided that it holds sufficient macroscopic plant-remains. Generally, however, the available samples will be too small and too poor in fossil fruits and seeds.

We have tried to remove that difficulty by means of microbotanical analysis. For this purpose a series of samples of Reuverian and Teglian Clays have been examined palynologically. Figure 2 shows the sections of some of the clay-pits in question and the analysed layers.

The results are given in the pollen-diagrams I–IV, constructed from the pollen-spectra of the samples (Figs. 3, 4, 5 and 6). Not all the pollen-grains met with have been entered. Only the most characteristic were recorded. We split them up into three groups: (*a*) Pollen-grains exclusively found in the Clay of Reuver: *Fagus*, *Liquidambar*, *Nyssa*, *Sciadopitys*, *Sequoia* or *Cryptomeria* and cf. *Taxodium*. (*b*) Pollen-grains inherent in the Clays of Reuver and Tegelen but so far not found in younger sediments in the Netherlands: *Carya*, *Phellodendron*, *Pinus haploxylon*, *Pterocarya* and *Tsuga*. (*c*) Pollen-grains occurring in the Reuverian, the Teglian and in younger Quaternary sediments: *Abies*, *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Picea*, *Pinus*, *Quercus*, *Salix*, *Tilia* and *Ulmus*.

Drawings and photographs of the pollen-grains mentioned under (*c*) have often been published. As to the other fossil grains, we may refer to the pictures in the papers of K. Rudolph (1935) and F. Thiergart (1937; 1940).

There can be little doubt about the identity of the pollen-grains either of *Fagus*, *Liquidambar*, *Nyssa*, *Sciadopitys*, *Carya*, *Phellodendron*, *Pinus haploxylon*, *Pterocarya* and *Tsuga* or of those of the

third group. The close resemblance of the pollen-grains of *Sequoia* and *Cryptomeria* obliged us to speak of "*Sequoia* or *Cryptomeria*." Probably these grains belong to *Sequoia*, as the Reuverian Clay has produced macroscopic remains of that genus but up to the present not of *Cryptomeria*. The grains recorded under "cf. *Taxodium*" may originate from different genera of the *Cupressaceae* and the *Taxodiaceae*. Pollen-grains of *Tsuga* occur in two types: one with a marginal fringe and another lacking such ornament. The former is fairly rare.

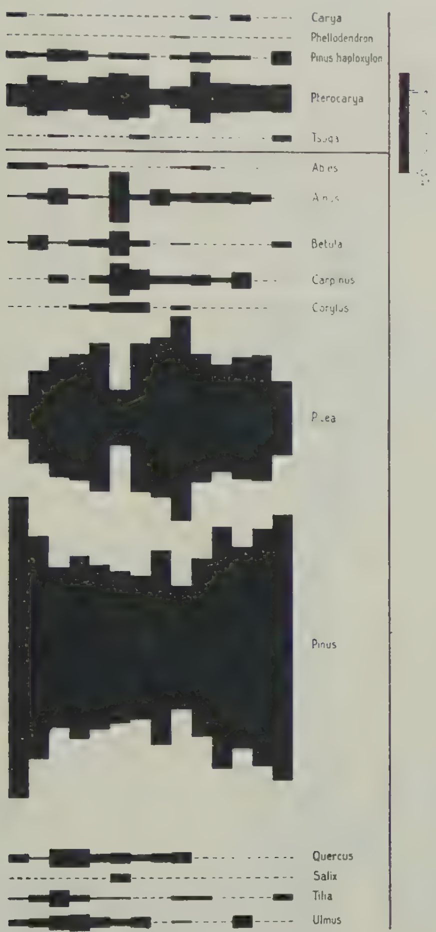

FIG. 3.—*Tegelen: Russel-Tiglia Clay-Pit.*
Pollen-Diagram I.

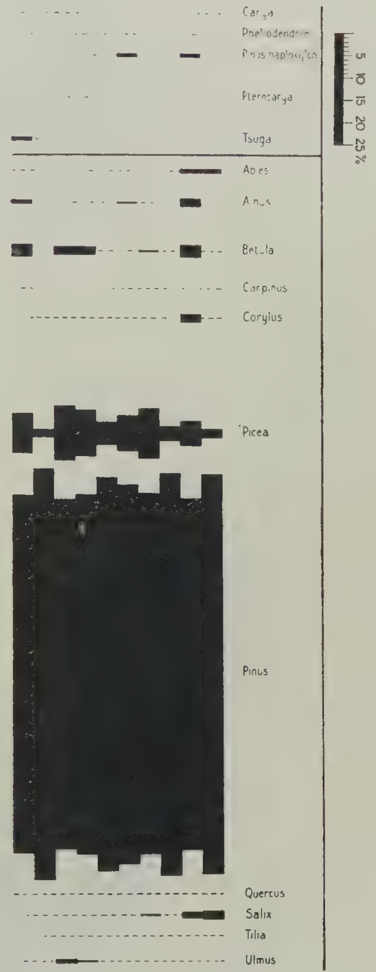

FIG. 4. *Tegelen: Kurstjens Clay-Pit.*
Pollen-Diagram II.

Pollen-grains of *Pseudolarix* closely resemble those of *Pinus*. As cone-scales and a dwarf-shoot of *Pseudolarix* have been found in the Clay of Reuver (Florschütz, 1925), it is possible that pollen-grains of that tree form part of the *Pinus*-percentages in the diagrams of Reuver and Swalmen. There is a satisfactory conformity between the diagrams of Reuver and Swalmen. Further discussion of these diagrams seems superfluous within the scope of this paper.

Apparently the diagram of Tegelen-Russel-Tiglia is the complement of that of Tegelen-Kurstjens which evidently reflects a preceding phase of the forest-history. This is in accordance with the situation of the clay-layers in question, as the one in the Kurstjens' pit lies on a lower level (see sections, Fig. 2).

The small number of particular pollen-grains in the clay of Tegelen-Kurstjens is remarkable. Only *Tsuga* and *Pinus haploxylon* have been found and moreover sporadically. This phenomenon points to the influence of the Early Glaciation or part of it on the Pliocene vegetation. As is shown by the

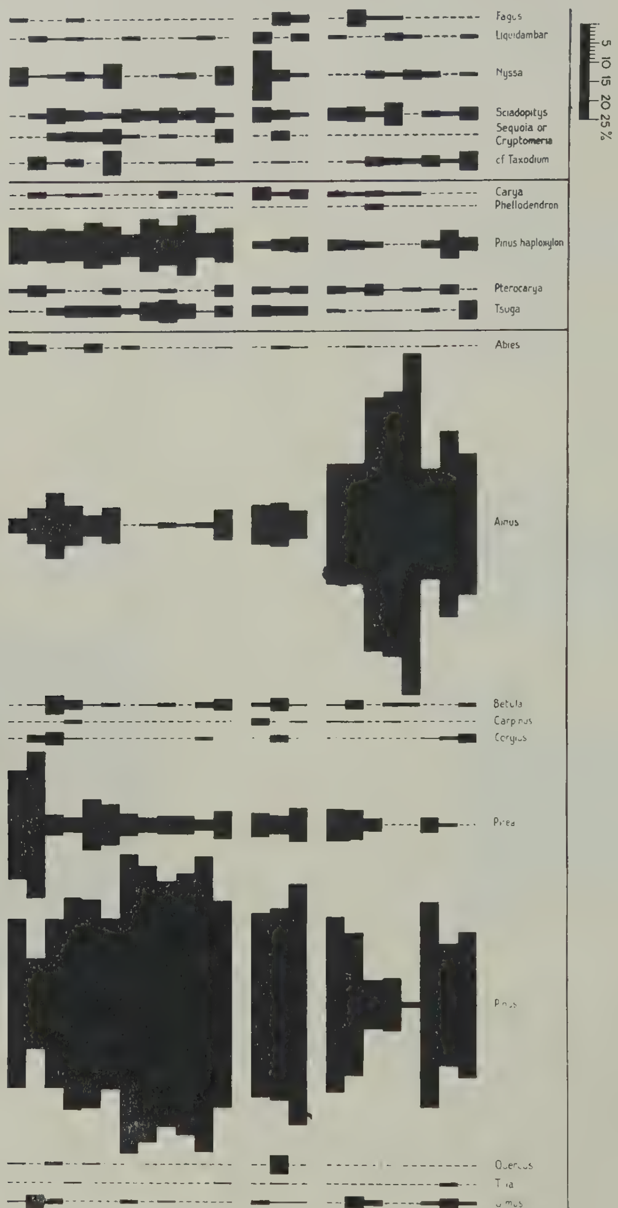

FIG. 5.—*Reuver: Icksberg Clay-Pit.*
Pollen-Diagram III.

diagram of Tegelen-Russel-Tiglia, the forests again became richer when the first interglacial or interstadial time had further advanced, but several interesting trees never returned.

It is now possible to trace the Pliocene-Pleistocene boundary in series of borehole-samples suitable for pollen-analysis. We have applied this method to the samples of browncoal and humic clay from a

deep boring near Budel. Figure 2 shows the section and the depths of the analysed layers. From diagram V (Fig. 7) one may deduce that the strata between 135·60 and 160·50 metres are synchronic with the Reuverian Clay and that those between 100·50 and 111·50 metres belong to the Tegelen horizon. Consequently, the boundary we are seeking may be supposed to lie between 111·50 and 135·60 metres. The humic clay-layer at 77·50 m. presumably dates from a younger Pleistocene time.

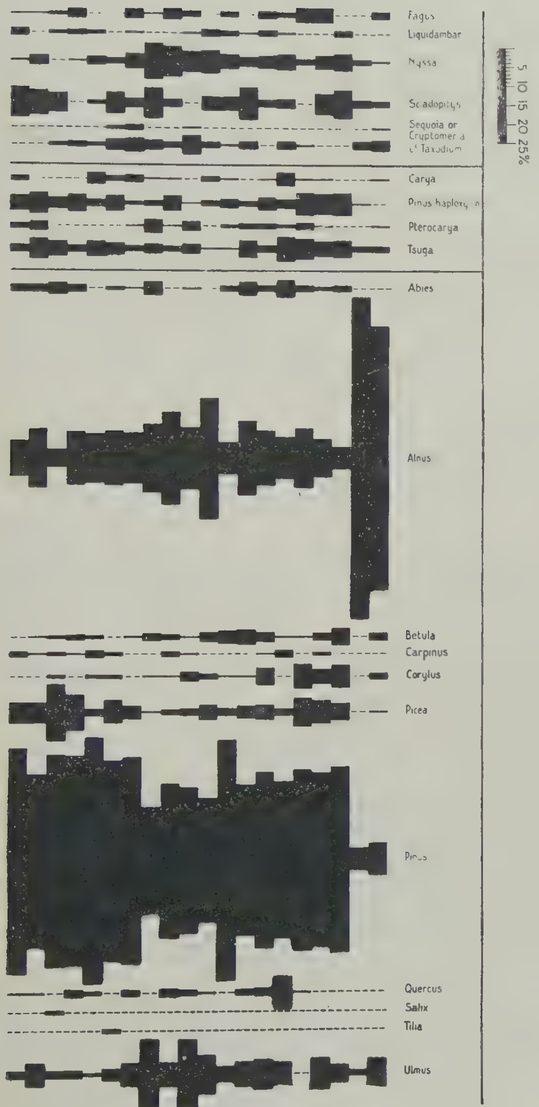

FIG. 6.—*Swalmen: Janssen-Willemsen Clay-Pit.*
Pollen-Diagram IV.

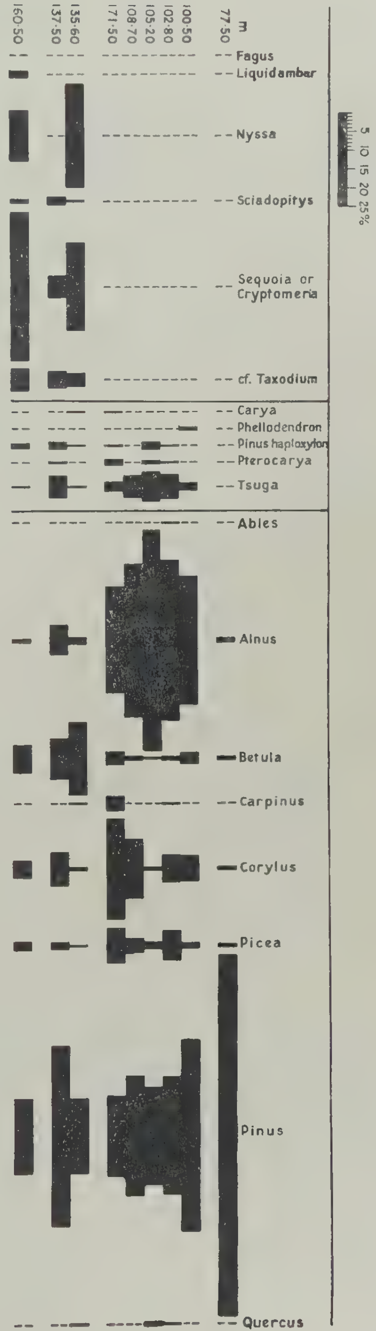

FIG. 7.—*Budel: Deep Boring.*
Pollen-Diagram V.

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ON THE IMPORTANCE OF THE ELEPHANTS IN THE PLIOCENE-PLEISTOCENE BOUNDARY AND THE STRATIGRAPHY OF THE PLEISTOCENE IN EUROPE

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RÉSUMÉ

J'estime, comme un certains nombre d'auteurs (dont E. Haug), que le Pléistocène commence avec le Villafranchien c'est à dire avec le début de l'extension des glaciers alpins.

Au point de vue de la faune terrestre, le Pléistocène ainsi conçu se caractérise par l'apparition de trois genres mammaliens émigrés de l'Asie: le genre *Elephas*, le genre *Equus* et le genre *Bos*.

En ce qui concerne le genre *Elephas*, les quatre espèces fossiles d'Europe: *E. planifrons* Falc. et Cautl., *E. meridionalis* Nesti, *E. antiquus* Falc., *E. primigenius* Blum., constituent des critères stratigraphiques importants pour le Pléistocène de nos régions.

LA STRATIGRAPHIE DU QUATERNAIRE DANS LE BASSIN DU NIEMEN

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RÉSUMÉ

Les études détaillées des auteurs sur la stratigraphie du Quaternaire dans le bassin du Niemen ont amené à des résultats qui jettent une nouvelle lumière sur le problème de la chronologie du Pléistocène en général.

On a pu reconnaître, sur le territoire en question, des dépôts appartenant à six périodes glaciaires indépendantes. Les dépôts glacigènes sont séparés dans maints endroits par des sédiments organogènes (tourbe, gyttia, craie lacustre). L'étude botanique de ces sédiments, exécutée surtout à l'aide de l'analyse pollinique, a démontré que les périodes séparant les poussées glaciaires différentes peuvent être considérées comme interglaciaires.

Pendant chaque période interglaciaire (on en peut distinguer cinq) le territoire du bassin du Niemen était domaine de riches forêts à *Quercetum mixtum* qui, vers le déclin de la période, se retiraient vers le Sud devant une nouvelle invasion du glacier continental nordique.

Malgré une certaine ressemblance, les associations forestières de chaque période interglaciaire gardaient leur habitus individuel et leur propre tendance d'évolution. Aucune trace d'éléments tertiaires.

Certaines observations concernant le Quaternaire de la Pologne centrale permettent de constater la validité du nouveau schème stratigraphique pour un vaste territoire de la plaine européenne.

LE Quaternaire du bassin du Niemen était depuis longtemps objet des études des géologues polonais. Les dernières années d'avant-guerre ont fort avancé notre connaissance de la stratigraphie de cette formation et sérieusement mis en doute les opinions anciennes sur l'existence, dans ce terrain, de traces de trois périodes glaciaires (Limanowski, 1934; Rydzewski, 1927). A savoir, entre 1933 et 1939, B. Halicki et L. Sawicki (1935–37) ont observé, dans les environs de Grodno, des dépôts appartenant à quatre au moins glaciations indépendantes. Pendant la guerre les auteurs de la communication présente ont eu la chance de poursuivre ces recherches aux environs de Wilno et sur le territoire de l'ancienne Lithuanie, qui était, au point de vue de la stratigraphie du Quaternaire, très peu étudiée. En 1945, au moment de la répatriation des auteurs en Pologne, ils disposaient de levées géologiques détaillées au 25,000-e de principaux fragments des grandes vallées du Niemen et de la Wilia au total montant à quelques centaines de km².

Grâce à la méthode de levées systématiques, poursuivies à l'aide de la force ouvrière (sondages, tranchées), on a pu rattacher les coupes voisines malgré la variabilité lithologique des horizons particuliers du Pléistocène. Les recherches ont été facilitées par l'abondance d'excellents affleurements dans les vallées sinueuses et profondement encaissées (jusqu'à 100 m.) du Niemen, de la Wilia et leur tributaires.

Des nombreuses coupes de sédiments interglaciaires organogènes ont fourni un riche matériel floristique, qui a pu être en partie sauvé et, en 1945, transporté en Pologne. Durant les années suivantes (1946–48) ce matériel était objet des études détaillées, principalement pollenanalytiques, de Mlles M. Bremówna et M. Sobolewska, collaboratrices de Muzeum Ziemi, dans l'Institut de Botanique de l'Université à Cracovie sous l'oeil bienveillant du professeur W. Szafer.Nb.ces études ne sont pas encore complètement achevées.

Dans la communication présente, vu les cadres restreints de la publication, les auteurs se borneront à présenter les résultats généraux de leurs recherches. La description des coupes particulières, la pétrographie des moraines et les diagrammes polliniques trouveront place dans une publication collective spéciale qui paraîtra à Varsovie en 1950 dans les " Acta Geologica Polonica "

I. STRATIGRAPHIE

1. *Substratum.*—Les dépôts pléistocènes reposent, dans le bassin du Niemen, sur les couches

appartenant au Primaire (Dévonien–Permien), ailleurs au Secondaire (Jurassique–Crétacé) resp. au Tertiaire.

Les plus récentes d'entre elles représentent le Néogène continental, probablement le Pliocène, qui remplit les dépressions du substratum plus ancien. Ce sont des sables quartzeux lignitifères à *Lauroxylon* et *Taxodium*, avec des intercalations argileuses ou graveleuses, d'origine fluviatile et lacustre.

La composition pétrographique des graviers néogènes présente un intérêt particulier. On y trouve, à côté de matériel du substratum très proche (silex crétacés), des fragments roulés de calcaires ordoviciens et gotlandiens silicifiés avec faune et des roches cristallines du massif Fénnoscandais. La dimension des deux derniers composants ne dépasse guère 2–3 cm. Ce matériel est identique avec celui qui a été observé par P. Krause (1933) dans le Néogène de la Sambie au littoral de la mer Baltique et dans quelques sondages profonds sur le territoire de l'ancienne Prusse Orientale.

Le caractère et la composition pétrographique de ces sédiments fluviaux confirment encore une fois la non-existence de la Mer Baltique vers le déclin du Néogène. Les rivières prenant naissance sur le massif Fénnoscandais tombaient dans un réservoir d'eau douce, qui s'étendait en Pologne Centrale et en Polésie. C'est à la fin du Pliocène seulement qu'il fut complètement remplit par l'accumulation de sables lignitifères et d'argiles bigarrées.

2. *Quaternaire préglaciaire.*—Dans quelques endroits, sur les sédiments indubitablement tertiaires gisent des sables et des argiles, dont l'âge géologique peut être déterminé comme quaternaire préglaciaire. Les restes végétaux trouvés dans ces sables dans le sondage profond à Pruzana (partage des eaux du Niemen et de la Prypeć) représentent les éléments purement quaternaires sans aucune trace de plantes tertiaires.

La stratigraphie des complèxes 1 et 2 témoigne donc, que toutes les glaciations dans le bassin du Niemen datent du Quaternaire, tandis que le Tertiaire sousjacent ne revèle aucune trace du phénomène glaciaire.

3. *Première glaciation.*—Les auteurs n'ont nulle part observé une moraine de fond normale de cette glaciation. Dans les coupes peu nombreuses, où affleuraient les couches basales du Pléistocène (environs de Wilno et d'Olita), c'était toujours une couche éluviale de pavetage, gisant en discordance directement sur le substratum préglaciaire.

Le caractère pétrographique du pavetage présente deux types différents: lorsqu'il se trouve sur le lit primaire, il conserve son inventaire rocheux à peu près complet, quoique en partie décomposé; sur le lit secondaire (remaniement du pavetage après sa décomposition chimique) il est fortement appauvri. Dans le premier cas on y peut constater un pourcent considérable de matériel local (Crétacé, Dévonien) à côté du nombreux matériel nordique avec des blocs erratiques cristallins jusqu'à 0·75 m. de diamètre. Dans le pavetage appauvri son inventaire rocheux est réduit aux silex crétacés, aux quartzites jotniennes et aux quelques variétés de roches cristallines, les plus résistantes contre les procès de désagrégation.

4. *Première période interglaciaire.*—Les sédiments organogènes de cette période sont représentés par des intercalations tourbeuses dans une série de sables fluviaux aux environs de Wilno (sondages) et par des bandes de detritus végétal dans un sédiment analogue près d'Olita. Les sables mêmes sont parfaitement lavés et leur ségrégation mécanique et pétrographique est fort avancée.

5. *Deuxième glaciation.*—Moraine de fond typique, grise ou brune, compacte, rarement jaunâtre et alors sableuse. Elle contient un nombre considérable de matériel rocheux crétacique.

6. *Deuxième période interglaciaire.*—Le climat de cette période est bien défini par les flores de Janiańce et Maksymańce sur le Niemen, auprès de l'ancienne frontière polono-lithuanienne. Les formations lacustres de ces localités (gyttia, tourbe, marne lacustre) ont une épaisseur de 4 m. Une autre série lacustre organogène (épaisseur 11 m.) a été constatée par Halicki et Sawicki à Kowalce près Grodno, mais les matériaux recoltés ont été perdus pendant la guerre avant l'achèvement de leur étude floristique et faunique.

Les sédiments fluviaux de cette période présentent quelques variétés de sables, dont les composants pétrographiques permettent de reconstruire partiellement le réseau hydrographique de certaines régions du bassin du Niemen.

7. *Troisième glaciation.*—Moraine de fond, presque toujours bipartite, à coloration inconstante. Matériel local restreint (Cénomanien).

8. *Troisième période interglaciaire.*—Les dépôts de cette période se composent de sédiments appartenant à deux cycles d'accumulation fluviale, séparés par une série argileuse. Cette dernière correspond à une stagnation presque complète des processus d'érosion. Dans maint endroit, surtout au cours inférieur du Niemen, les argiles mentionnées ont un aspect de sédiment des lacs de barrage glaciaires, quoique les argiles à varves typiques sont plutôt rares.

En s'appuyant sur ces faits on peut soupçonner l'existence d'une oscillation de l'inlandice, qui a atteint le littoral sud de la Mer Baltique sans avoir pourtant pénétré plus profondément dans le continent. Cette interprétation est complètement confirmée par le diagramme pollinique des gyttias et des tourbes fossiles de Zydowszczyzna (Jaroń, 1933), dont la stratigraphie correcte a été donnée en 1937 par Halicki et Sawicki (1935–37).

9. *Quatrième glaciation.*—Moraine de fond, habituellement rouge ou brune, quelquefois verdâtre (environs de Wilno). Souvent elle est complètement détruite et réduite au pavetage par l'érosion intense de la suivante période interglaciaire.

10. *Quatrième période interglaciaire.*—Son caractère est bien déterminé par l'étude des sédiments lacustres organogènes de Kmity sur la Wilia (entre Wilno et Kowno) ainsi que de Poniemuń et Samostrzelniki aux bords du Niemen (environs de Grodno). Les analyses polliniques des deux dernières coupes ont été exécutées par J. Dyakowska (1936) et J. Trela (1935–36); leur position stratigraphique cependant a été interprétée erronément (Rydzewski, 1927).

L'épaisseur de sédiments fluviaux de cette période interglaciaire dépasse souvent 30 m.

11. *Cinquième glaciation.*—Moraine de fond rouge, rarement grise, dans maint endroit bi- et même tripartite (oscillations).

12. *Cinquième période interglaciaire.*—Les marnes lacustres et les tourbes fossiles de Nieciosy sur le Niemen (non loin de l'ancienne frontière polono-lithuanienne) ont fournis le plus complet matériel pour la définition du climat de la dernière période interglaciaire dans le bassin du Niemen. Les dépôts organogènes du même âge à Cimoszkowicze (env. de Nowogródek) ont permis à Gawlowska (1934) de reconstruire à peine un fragment de la période en question.

Sédiments fluviaux fréquents, mais peu caractéristiques.

13. *Sixième glaciation.*—La moraine de fond de la dernière glaciation a couvert la partie ouest du bassin du Niemen. Sa limite est et sud passe par les environs de Grodno, Wilno et Wilejka. L'aspect de la moraine est variable. Les faciès les plus fréquents sont représentés par une argile à blocaux compacte rouge ou bien moins compacte brune. Quelques oscillations de l'inlandice ont provoqué, dans certaines régiones, la formation de 2–3 niveaux indépendants d'argiles morainiques.

L'oscillation principale devait avoir une ampleur considérable, vu l'existence de dépôts interstadiaires avec faune de mollusques et restes végétaux à Komaryszki à l'Est de Wilno (Halicki et Urbański, 1936). Le caractère de la faune est semblable à celui qui a été cité par les géologues allemands (Hess v. Wichdorff, 1914) du territoire de l'ancienne Prusse Orientale (période interstadiaire " masourienne ").

Les terrains à l'Est de l'extension maximum de la dernière calotte glaciaire portent une couverture locale de loess éolien, dont l'épaisseur atteint par places une dizaine de mètres (environs de Nowogródek).

14. *Période postglaciaire.*—La formation des sédiments de terrasses fluviales, des tourbes, des travertins, etc., débute au déclin du Pléistocène et se poursuit pendant le Holocène jusqu' à nos jours. Quoique, aussi dans l'histoire des temps postglaciaires, les recherches des auteurs ont apporté un nouveau matériel scientifique, ils le passeront sous silence afin de discuter plus amplement les résultats concernant la question fondamentale de leur communication.

STRATIGRAPHY OF THE PLEISTOCENE IN THE NIEMEN BASIN (POLAND)

Stratigraphical Divisions	*Deposits*	*Sections with Organic Remains*	*Character of Flora at the Optimum-phase*	*Climatic Conditions*	*Geological and Morphological events*
Sixth Glaciation: Later phases	Moraine	—	—	Glacial	Glaciation of the NW-part of the Niemen basin In the SE-part solifluxion
Sixth Glaciation: Interstadial	Sands, lacustrine clays	Komaryszki, E. of Wilno	*Salix* spp. (Molluscan fauna associated)	Subarctic?	Sedimentation Weak erosion
Sixth Glaciation: Earlier phases	Moraine	—	—	Glacial	Glaciation of the NW-part of the Niemen basin In the SE-part: deposition of loess
5th (last) Interglacial	Peat, lacustrine marls River sands	Nieciosy on the Niemen, Cimoszkowicze near Nowogródek	*Quercetum mixtum* up to 68% *Corylus* up to 222% (after M. Sobolewska)	Warmer than to-day	Sedimentation Moderate erosion and denudation Weathering
Fifth Glaciation	Moraine	—	—	Glacial	Glaciation
4th Interglacial	Peat, gyttia, lacustrine marls River sands	Kmity on the Wilia; Poniemuń, Samostrzelniki and some other localities on the Niemen (near Grodno)	*Quercetum mixtum* 65% (Pleist. maximum of *Tilia* 60%) *Corylus* up to 275% Pleist. maximum of *Carpinus* (up to 76%) (after Dyakowska, Sobolewska and Trela)	Much warmer than to-day	Sedimentation Intense erosion and denudation Weathering
Fourth Glaciation	Moraine	—	—	Glacial	Glaciation

3rd Interglacial — Upper part	Peat and gyttia — River sands	Zydowszczyzna near Grodno	*Querc. mix.* up to 8% *Corylus* up to 5% *Abies* up to 22% *Picea* up to 19%, *Larix*	Wet and cooler than to-day	Sedimentation
3rd Interglacial — Middle part	Peat and gyttia — Lacustrine and laminated clays	Zydowszczyzna near Grodno — Male Dugnie on the Mereczanka	Coniferous forests with *Betula* and *Larix*	Nearly subarctic	Stagnation Ice advancing Sedimentation
3rd Interglacial — Lower part	Peat and gyttia — River sands	Zydowszczyzna near Grodno	*Quercetum mix.* up to 16% *Corylus* up to 16% *Carpinus* up to 54% *Abies* up to 54% *Picea* up to 60%, *Larix* (after Jaroń)	Wet and as warm as to-day	Weak erosion Weathering
Third Glaciation	Moraine	—	—	Glacial	Glaciation
2nd Interglacial	Peat, gyttia, lacustrine marls and clays River sands	Janiańce-Maksymańce Kowalce, Kapitaniszki on the Niemen between Grodno and Kowno	*Quercetum mix.* up to 70% (Pleist. maximum of *Quercus*, 67%) *Corylus* up to 300% (after M. Bremówna)	Much warmer than to-day	Sedimentation Moderate erosion and denudation Weathering
Second Glaciation	Moraine	—	—	Glacial	Glaciation
1st Interglacial	River sands with plant remains	Wilno, Olita	? Present: *Quercus*, *Pinus*, *Alnus* (after W. Szafer)	Probably not cooler than to-day	Sedimentation Intense erosion, weathering and denudation
First Glaciation	Pavement or pebble-bed with Scandinavian boulders up to 0.75 m. diam.	—	—	Glacial	Glaciation
Preglacial Quaternary	Clays, river sands with plant remains and peaty lenses	Pruzana (on the Niemen-Pripet water-divide)	? Found: *Pinus silvestris*, *Carpinus betulus*, *Juniperus communis*, *Populus sp.* (after W. Szafer)	Not cooler than to-day	Sedimentation Intense erosion, weathering and denudation

TERTIARY/Neogene/ Sands with lignite (Lauroxylon, Taxodium)

II. PERIODES INTERGLACIAIRES

Le nouveau schème stratigraphique du Pléistocène, établi dans le bassin du Niemen, est en divergeance avec les opinions les plus répandues sur la chronologie du Quaternaire de la plaine européenne. Cette circonstance oblige les auteurs de citer, à côté des matériaux publiés, quelques données préliminaires concernant les études pollenanalytiques de Mlles Bremówna et Sobolewska avant qu'elles les auront publié en détail. Il en sortira, que toutes les cinq périodes, séparant les grandes poussées de l'inlandice nordique, peuvent être considérées comme interglaciaires et non interstadiaires.

1. *Période quaternaire préglaciaire.*—Les restes végétaux du sondage profond à Pruzana ont été déterminés par le prof. W. Szafer (Halicki, 1935). Ils sont représentés par *Carpinus betulus*, *Populus* sp., *Pinus silvestris* et *Juniperus communis*. La liste n'est pas longue, on en peut pourtant tirer une conclusion sur le caractère tempéré du climat préglaciaire dans notre région.

2. *Première période interglaciaire.*—Elle est la seule où manquent les données plus précises sur le caractère de la flore et l'évolution climatique.

Les échantillons des intercalations tourbeuses provenant des sondages profonds de Wilno ont été malheureusement perdus au cours des événements de la guerre. La seule indice floristique sur la période en question provient du sondage N 29 à Wilno; les quelques fragments de bois extraits des sables datant sans aucun doute de cette période ont été déterminés par le Prof. W. Szafer comme appartenants à *Pinus* sp., *Quercus* sp., *Alnus* sp. Il est donc possible de constater dans le bassin du Niemen, l'existence de forêts mixtes aussi durant la première période interglaciaire.

En faveur d'une longue durée de la période en question on pourrait encore rappeler le fait, que la moraine de fond de la première glaciation a été détruite par l'érosion et son inventaire rocheux a subi souvent une désagrégation chimique fort avancée (pavetage appauvri) avant la deuxième invasion du glacier nordique. La même opinion résulte du caractère des sédiments fluviaux de cette période.

3. *Deuxième période interglaciaire.*—Durant l'optimum climatique la Chênaie mixte atteint dans les sédiments organogènes de Janiańce et Maksymańce 70%; le *Corylus* monte jusqu'à 300% (analyses polliniques de Mlle M. Bremówna). Le pourcent du chêne atteint son maximum absolut (67%) jamais dépassé durant les autres périodes interglaciaires. Climat chaud avec certaines empreintes continentales.

4. *Troisième période interglaciaire.*—Contrairement à la période interglaciaire précédente son climat était tempéré et humide. En plein accord avec la stratigraphie (cf. I. Stratigraphie; Jaroń, 1933) le diagramme pollinique de Zydowszczyzna (Jaroń, 1933) revèle l'existence de deux optimums séparés par une période froide.

L'optimum inférieur contient 16% de Chênaie mixte et 18% de *Corylus*, mais encore 54% de *Carpinus*; l'optimum supérieur—8% de Chênaie mixte, 5% de *Corylus* et 8% de *Carpinus* seulement. Au temps de l'oscillation froide, qui sépare les deux optimums, les arbres termophiles disparaissent. Le rôle principal pendant toute la période jouent les conifères hygrophyles: *Abies* (jusqu'à 54%) et *Picea* (jusqu'à 60%); *Larix* présent en quantité considérable.

5. *Quatrième période interglaciaire.*—Son climat est suffisamment reflété dans les diagrammes de Kmity (analyses poll. de Mlle M. Sobolewska), de Poniemuń et Samostrzelniki (Dyakowska, 1936; Trela, 1935). A l'optimum climatique la Chênaie mixte atteint 65%, le *Corylus* 275%. Dans l'association de la Chênaie la première place est occupée par *Tilia* (jusqu'à 60%). Le *Carpinus*, qui suit la phase de la Chênaie mixte, atteint son maximum absolut quaternaire (76%).

6. *Cinquième période interglaciaire.*—Au point de vue climatique elle revèle une certain ressemblance avec la période interglaciaire précédente (analyses poll. de Mlle M. Sobolewska). Les forêts de la phase optimum ont jusqu'à 68% de la Chênaie mixte et jusqu'à 222% de *Corylus*. Les divergeances principales consistent dans une différente succession des arbres particuliers, adhérant aux associations forestières consécutives.

L'analyse des flores fossiles, appuyée par les études stratigraphiques détaillées a permis de préciser les différences et les analogies dans l'histoire des forêts des périodes interglaciaires consécutives dans

le bassin du Niemen. Malgré cela il serait encore difficile de risquer un essai de synchronisation de ces flores avec les flores interglaciaires de la Pologne centrale et méridionale. On devrait se borner aujourd'hui à constater les ressemblances de certaines d'entre elles avec celles du Niemen. Le diagramme pollinique de Dzbanki et Szczerców (Piech, 1932) rappelle par ex. l'évolution forestière de Maksymańce-Janiańce (2-e pér. intergl.), le caractère de la flore de Zydowszczyzna dans notre région (3-e pér. intergl.) coïncide avec celui d'Olszewice (Lilpop, Trela, 1929), etc. Ces convergeances, parfois frappantes, n'autorisent pas cependant de tirer des conclusions prématurées sur leur âge géologique identique.

Dans le prochain avenir les auteurs projettent une révision générale des coupes interglaciaires de la Pologne au point de vue de leur position stratigraphique. Après cela il sera peut-être plus facile de résoudre aussi la question mentionnée. Certaines observations récentes de L. Sawicki (1934) et de K. Pozaryska (1948) permettent d'espérer, que le nouveau schème stratigraphique admettant l'existence de six glaciations sera confirmé dans d'autres régions.

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THE UPPER AND LOWER LIMITS OF THE PLEISTOCENE*

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ABSTRACT

The metabolism of mammals makes them less sensitive than other animals, whether terrestrial or aquatic, to small environmental changes. Their migrations are so swift that the time factor may be ignored. Hence mammals are well suited for use as guide fossils in making wide correlations. As a rule geological periods are separated by fiducial lines of practical convenience, based on the appearance of immigrant forms. In the Tertiary, the Pontian and Villafranchian contain new faunas; they mark the beginning of the Pliocene and Pleistocene respectively.

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AMERICAN FLUVIAL PLIOCENE DEPOSITS BORDERING THE WESTERN MARGIN OF THE CUMBERLAND PLATEAU

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ABSTRACT

The Mid-Tertiary (Miocene) peneplain (900-1,100 feet A.T.) borders the Cumberland Plateau (1,500-2,200 feet A.T.) on the west, as the latter does the Appalachian Mountain province from New York to Alabama in the eastern part of the United States of America. Present-day drainage, the Ohio river and its major westerly and north-westerly flowing tributaries, has entrenched itself into the Mid-Tertiary peneplain to levels ranging from 350 to 600 feet A.T. Remnants of old, abandoned stream channels clearly marked, in most cases, by topography and fluviatile boulders, cobbles, gravels, sands, clays and silts, have been found and described in the States of Ohio, West Virginia, Kentucky, Tennessee and Alabama. These old, high-level stream deposits are all post-Miocene and pre-Glacial (Pleistocene). They occur at varying levels from 700 to 950 feet; are predominantly siliceous, transported materials derived by stream erosion from sandstone, quartzite, conglomerate and cherty limestone parent ledges, principally Carboniferous; range in thickness from 1 to 75 feet and are of Pliocene age. Usually void of contemporary fossils—vertebrate and invertebrate—they grade gradually downstream into the Lafayette formation (Hilgard, 1885) which covers broad portions of the Mississippi river valley.

INTRODUCTION

IN the eastern United States, waters falling west of the Allegheny mountains are, for the most part, gathered by tributaries flowing to the west, north-west or south-west and debouched into the master stream of the area—the south-westerly flowing Ohio river. In the course of their westerly movement these waters, resolving themselves into a number of grand rivers, traverse two plateaux of regional significance. The most extensive, elevated and easterly of these uplands is the Cumberland–Kittatinny plateau. Touching New York on the north-east and western Alabama on the south-west its length is about 750 miles and its area is fully 85,000 square miles. This great, rugged upland, attaining usual elevation, ranging from about 1,500 to 2,200 feet A. T. is tilted to the west. It is bounded on the east and south-east by the superior altitudes of the Appalachian mountains proper.

Immediately to the west of the Cumberland–Kittatinny plateau and interfingering into it is another plain of somewhat lesser elevation—the Lexington–Highland Rim plateau which exhibits, in its best expression, elevations ranging from about 900 to 1,000 feet A. T. Though parallel throughout to the deeply incised Cumberland upland, the Lexington–Highland Rim plateau is not nearly as long, probably not more than 400 miles in length from Central Southern Ohio to northern central Alabama. Correspondingly it encompasses a much smaller area—about 30,000 square miles. The Cumberland–Kittatinny plateau was formerly held to be the end-product of Cretaceous stream erosion and peneplanation, but is now quite generally regarded as of early Tertiary (Eocene) origin. The thousand-foot lower, Lexington–Highland Rim plateau is held to be the result of Mid-Tertiary (late Miocene) peneplanation. Much of the original extent of the Lexington plateau in central and northern Ohio has been obliterated by glaciation.

Along the master streams of western Pennsylvania, West Virginia, southern Ohio, central and eastern Kentucky, central Tennessee and northern Alabama, erosion has entrenched itself 350 to 600 feet below the medial levels of the Lexington–Highland Rim plateau and has begun by lateral planation and solution the creation of a new and lower base level which is typified to-day by the medial levels

of the Nashville basin in central northern Tennessee. Similar elevations can be obtained along and close to lines of entrenched drainage in central northern Kentucky, southern Ohio, western West Virginia and south-western Pennsylvania.

FLUVIAL PLIOCENE

Postulating the Lexington–Highland Rim peneplain as late Miocene, all stream entrenchment, immediately and for some distance below its medial level, must necessarily be Pliocene. Mid-Tertiary base-levelling in this part of the eastern United States was followed by late Tertiary uplift and stream rejuvenation. Unconsolidated sediments, principally insolubles, consisting of quartzite boulders and cobbles, geodes, sandstone slabs, subangular cherts, quartz pebbles, silica sands, silts, loams and clays, the source or parent ledges of which—except in the last three instances—can be located close to or within the Cumberland plateau, are found to-day resting on high-level terraces and ridges, and in abandoned channels ranging from 650 to 950 feet A. T., along and close to the master streams of the combined Lexington–Cumberland plateaux. These deposits are here defined as Pliocene fluvial sediments.

At no place within the Lexington–Highland Rim plateau do they attain an elevation greater than 950 feet. The gradients of these old, abandoned Pliocene terraces and channels rise, however, above 950 feet and finally above 1,000 feet A. T. as their locations and courses are traced farther to the south-east into the Cumberland plateau. Theoretically, at least, these Pliocene fluvial gradients and their characteristic sediments—cobbles, gravels and sands—must continue to rise gradually toward the head waters of each individual river.

COASTAL PLIOCENE

Downstream in the Ohio, Cumberland and Tennessee valleys to the west, south-west and north-west in Kentucky, these old river sands and gravels are found at increasingly inferior elevations and gradually grade into the upper part of the unconsolidated Lafayette formation, a coastal plain deposit definitely of late Tertiary age, presumed Pliocene. The Lafayette as originally described has broad expanse in southern Alabama and southern and central Mississippi. It extends northwardly in an irregular pattern, some 40 to 60 miles east of the Mississippi river, principally as separated ridge-top deposits of frequently restricted and largely unmapped area into western Tennessee and western Kentucky where it attains a thickness varying from 25 to 50 feet, and broad areal extent.

The continuity of the Lafayette gravel formation of the Jackson Purchase of western Kentucky up the valleys of the Tennessee, Cumberland, Ohio and Kentucky to the high-levels of the *Irvine* gravels of the old intermediate valley of M. R. Campbell (1898), was recognized by A. M. Miller (1919) and has more recently been affirmed by A. C. McFarlan (1943). In Alabama, G. I. Adams, L. W. Stephenson and others (1926) have stated that the ridge-top gravels, sand and loam resting on the Cretaceous and older rocks are of ancient, fluvial origin. They have defined them as Pliocene. These fluvial gravels were included in the Lafayette by E. A. Smith and others (1894).

SOUTHERN PROVINCE

Apparently J. M. Safford (1856) of Tennessee was the first to recognize the separate stratigraphic value of the old fluvatile gravels in the South now known as part of the Lafayette formation. He stated: " The *Superficial Gravel-beds* of Wayne, Hardin and adjoining counties in the valley of the Tennessee river, just north of the Alabama line are coarse and often ferruginous or conglomerate and are . . . found in these counties overlying the other Cretaceous and mid-Paleozoic formations." Coastal plain sands and gravels of western Tennessee and Alabama, now recognized as Pliocene, were included by Safford (1864) in his " Orange Sand Group," and later (1869) in its synonym, the LaGrange formation which is now regarded as Eocene.

The shifting of these beds from their original erroneous classification as Cretaceous in 1864 to Eocene in 1869, coupled with a varying lithology over broad districts, early led to considerable

uncertainty among geologists as to the age and correlation of these deposits. E. W. Hilgard (1885) in Mississippi first proposed the formational term Lafayette, and later (1892) discussed the origin of the Lafayette in some detail. The controversy continuing, however, Safford and Killebrew (1900) undertook to settle it by classifying the Lafayette as " Neocene or upper Tertiary "—the equivalent of the Pliocene.

Three years later, Hayes and Ulrich (1903) were at some pains to describe, but failed to classify as to age, coarse gravels consisting of thoroughly water-worn cherts and vein quartz pebbles occurring on the ridges of the western Highland Rim plateau within the Columbia Quadrangle of central Tennessee. L. C. Glenn (1906) addressing himself to the problem of the Lafayette gravels defined this formation as Pliocene. This position was affirmed by Blackwelder (1912) who in a general discussion of the Pliocene, described " the Lafayette formation as . . . of fluvatile origin—a broad coastal plain deposit. The Lafayette sediments extend farther inland than almost any of the other coastal formations. Along the inland border of their outcrop they usually occupy the top of hills, the intervening portions having been removed during the erosion of the valleys."

Fluvial chert and quartz gravels occurring in Rutherford County, Tennessee, somewhat below the level of the Highland Rim plateau were classified as Pliocene by Galloway (1919). Lusk (1928) called attention to similar gravels—Fort Payne cherts and Pottsville quartz pebbles—occurring five-and-a-half miles south of Celina, Tennessee, on abandoned terraces of the Cumberland River at levels below the Highland Rim plateau. Jewell (1931) affirmed the Pliocene age of high terrace gravels in Hardin County, Tennessee, and Theis (1936) observing similar beds of sand and gravel, held "at least some of the terrace deposits on the streams of south central Tennessee will be found to be Pliocene." Born and Burwell (1939) followed suit and held the high-level fluvial gravels in southern Clay County, Tennessee, to be Pliocene.

CENTRAL PROVINCE

In Kentucky, Lyon (1857) was the first to observe upland gravels, recording the excellent exposure of fluvial deposits found in the Flatwoods just west of Ashland in a brief footnote of the second volume of the first geological survey of the Commonwealth. Really they belong to an abandoned, high-level meander of the old, pre-glacial (Pliocene) Teays river, but Andrews (1874) who described the Flatwoods sand and gravel exposure in some detail, erroneously thought, like Lyon, that this feature was of glacial origin. Shaler (1877), while State Geologist of Kentucky, was the *first* to call attention to the existence of occasional beds of " high-level, stream gravels bordering the deep river valleys of the Commonwealth," but he named no specific localities. Eighteen years later Miller (1895) described in some detail the fluvial gravels found on the high terraces of the Kentucky, the Licking and the Cumberland rivers.

M. R. Campbell (1898) while executing the geology of the Richmond (Kentucky) folio, saw the stratigraphic value of these fluvial gravels and named them the *Irvine* formation of Neocene (Pliocene) age. Foerste (1906), picking up the work begun by Campbell, extended the areal occurrence of the Irvine formation and described the nature of these fluvial deposits at a number of separated localities in the old, high-level valley of the Kentucky river.

NORTHERN PROVINCE

Meanwhile Leverett (1902), in a monumental work on glaciation and the effects of glaciation in the Ohio valley during the Pleistocene, mapped and described a number of abandoned, pre-glacial (Pliocene) river valleys in Kentucky, Ohio, West Virginia and Pennsylvania. His description of the " Tertiary fluvial deposits " (Irvine sand and gravels) of the valleys of the lower Ohio and its tributaries has become classic, as have his outlines of the Pliocene valleys of the Allegheny, Monongahela, Kanawha (or Teays), as well as of the Licking and Kentucky, and in the State of Ohio of the Muskingum and other rivers of lesser significance. In southern Indiana Cox (1871–72) had previously found and described fluvial gravels occurring on the non-glaciated northern bluffs of the Ohio near Cannelton at about 700 feet A. T., and Leverett picking up the thread of discovery, carried these Pliocene deposits

many miles further upstream to the north-east. Tight (1903) followed closely Leverett's work and revealed by description and map the courses of many Pliocene rivers in south-eastern Ohio and West Virginia, the Teays, the Marietta, the Albany, the Chillicothe to name but a few, though perhaps the most interesting ones.

Each of these abandoned stream channels originally exhibited fluvial Pliocene deposits—principally sands and gravels. Some of these deposits are still observable on outcrop as high terrace beds. Others, perhaps most of them, after the southernmost limit of the Pleistocene continental ice-sheet is reached, in their ancient, down-stream course to the north-west, are covered and entirely obliterated. As one ponders the detailed and excellent descriptions supporting the interpretations and maps of Leverett and Tight, one is moved to admiration of the pioneering work done by White in the Beaver valley (1878) and Carll in the upper Ohio (Allegheny) valley (1880) in defining by high terrace gravels and unglaciated topography the courses of these old, northern rivers of the Pliocene period.

ABANDONED CHANNELS

Late in 1929, after several years of manuscript preparation, the writer issued the currently used geological map (Jillson, 1929) of the Commonwealth on which the broad, areal sweep of the Lafayette formation (Pliocene) is shown extending westwardly from the lower Cumberland to the Mississippi river. Lack of detailed mapping made it impossible to show the fluvial Pliocene gravels extending on up the river valleys to the east, north-east and south-east.

Some years later, in the mid-summer of 1941, a casual reconnaissance of the then newly graded course of U.S. Highway No. 60 resulted in the discovery of an abandoned, high-level channel of the Kentucky river at a point three and a half miles west of Frankfort, Kentucky. Fluvial sands, gravels and silts were here found to be 26 feet thick at 725 feet A. T. in a definitely rock-cut channel in the Woodburn limestone (Trenton-Ordovician). Detailed mapping was undertaken later, and in 1943 a pamphlet (Jillson, 1943) with map detailing the lately discovered, ancient upland stream course, 22 miles in length, was issued. It was No. 1 of the *Pliocene River Series.*

Since then, as time has permitted, field work in the lower valley of the Kentucky tracing fluvial deposits of high-level sand, clays and gravels and their in-and-out accompaniment—the high-level rock-cut channel—has been carried forward intermittently with the result that twelve separate pamphlets, each mapping and describing a part of the *Pliocene Kentucky River* (Jillson, 1943–48) have been issued. Levels of the rock-cut floors of these several Pliocene channels have varied from 650 to 920 feet A. T. and have ranged from 150 to 425 feet above the rock-cut floor of the present Kentucky river. Evidently several stages of entrenchment are represented. Thicknesses of fluvial Pliocene sediments have frequently changed rapidly—from 1 to 75 feet. Taken together, these mapped and described segments of the old, high-level river exhibit its ancient course throughout the greater part of the Bluegrass region—across the Lexington plateau and the Cincinnati Arch transversely—from the Paint Creek Ferry and the Madison County line, on downstream to the Ohio river and the village of Brooksburg, a few miles above Madison, Indiana. This involves a mapped distance of about 190 channel miles. It is believed to be the first, detailed and extended geologic work to be done in the United States that has made stratigraphic use of the patchy, elevated, fluvial Pliocene deposits.

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FOSSIL HOMINIDS FROM THE LOWER PLEISTOCENE OF JAVA

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ABSTRACT

In the Lower Pleistocene of Java occur three different types of fossil hominids: (1) ***Meganthropus palaeojavanicus*** von Koenigswald, represented by two jaw fragments and several isolated teeth. The jaw found in 1941 is in size not inferior to a gorilla's, but the symphysis, showing the beginning of the mental spine, is essentially human. (2) A heavy type of *Pithecanthropus* is indicated by fragments of a skull (*Pithecanthropus* IV), including the maxilla, which show a diastema (" simian gap ") in front of the canine; and a lower jaw (*Pithecanthropus B.*) This form is stratigraphically and morphologically different from Dubois' *Pithecanthropus erectus*. The baby skull described by the author as " *Homo modjokertensis* " probably belongs to the same species (*Pithecanthropus robustus* Weidenreich). (3) *Pithecanthropus dubius* von Koenigswald, represented by a fragment of lower jaw (1939) and isolated teeth. The molars show an unusual deviation from the " *Dryopithicus* pattern."

INVESTIGATIONS in Java between 1931 and 1941 have shown that the Pleistocene of Java can be divided into three divisions. The Upper Pleistocene is known from the high level river terraces of Ngandong, the Middle Pleistocene is represented by the Trinil layers (containing Dubois' type of *Pithecanthropus erectus*) while the Djetis layers belong to the Lower Pleistocene.

Typical of the Djetis fauna are archaic elephants, *Leptobos*, *Chalicotherium*, *Epimachaiodus* and several antelopes. The faunal association can be correlated with the Pinjor fauna of India and is of Villafranchian affinity.

Of general importance is the occurrance of fossil hominids in the Djetis fauna. The first discovery was a baby skull found near Modjokerto in Eastern Java in 1936 and called *Homo modjokertensis*, although it was evident that this was the skull of a young *Pithecanthropus*. Because of the undoubtedly human nature of this skull the name *Pithecanthropus* however, was opposed, as, according to Dubois, his *Pithecanthropus* was an anthropoid. It was not before 1937 that an additional skull of *Pithecanthropus erectus* proved the human nature of this disputed fossil. The new finds come from the region of Sangiran near Solo, Central Java, where the Pleistocene deposits are beautifully exposed and where the Djetis layers are developed as a black clay, deposited in a freshwater lake, while the Trinil layers are formed by tuffs, sandstones and conglomerates. Both formations have yielded human remains. Large scale collections could be made with special grants from the Carnegie Institution of Washington and the Rockefeller Foundation, while the Rockefeller Foundation and the Viking Fund, New York, generously enabled the author to work out his material at the American Museum of Natural History in New York.

Fragments of mandibles, all broken in the symphysis, differ so much from each other that they are proof of the existence of *three different types of hominids in the Djetis layers.*

(*a*) *Pithecanthropus modjokertensis* (v. Koenigswald).

The most common type of hominid in the Djetis layers of Sangiran is represented by a lower jaw, formerly called *Pithecanthropus B*, fragments of a skull and the larger part of the maxilla, formerly called *Pithecanthropus* IV, and a large number of isolated teeth. The jaw was originally described as belonging to *Pithecanthropus erectus* (1937). For morphological and stratigraphical reasons the skull

has been regarded by the author as a neotype of the form already indicated by the indifferent baby skull from Modjokerto. Without knowledge of the author, for purely morphological reasons Weidenreich has called the skull, which we formerly regarded as a male specimen of *Pithecanthropus erectus*, *Pithecanthropus robustus* Weidenreich, while he regarded at the same time the mandible as belonging to *Pithecanthropus erectus.*

In size, the specimens belong together. More particularly the character of the coarse wrinkles in the molars of the lower jaw is exactly the same as in the upper jaw. There can be no doubt that mandible B and skull No. IV belong to the same species, although to different individuals.

The lower jaw is heavy, and shows like *Sinanthropus* several foramina mentalia. The first molar is quadratic, the second is larger than the first while the third molar is still larger.

In the upper jaw the central incisors are extremely shovel-shaped, by far surpassing the condition observed in *Sinanthropus*. There is a marked diastema in front of the canines, which can also be observed in another small fragment. In a third fragment however, there is a contact facet on the canine, giving proof that this specimen had no diastema. As here the teeth are slightly smaller, we might assume that the diastema was only developed in the male individuals and already lost in the female. Canine, premolars and molars are arranged in one straight row. The massive canine was slightly protrusive. Two specimens of first premolars show that this tooth still had three roots; of the molars the second was larger than the first. In both cases we have the same conditions as in the anthropoids.

The skull, with the frontal part missing, is very thick with a pronounced occipital torus. The mastoid was long and pointed. The brain capacity was about 1,000 cc. for this male specimen.

(*b*) *Pithecanthropus dubius* v. Koenigswald

This rare form is indicated by a fragment of a lower jaw (discovered in 1939) and one isolated lower molar only. The jaw has one large foramen mentale and, on the inner side, a distinct fossa sublingualis. The molars show a very curious highly specialized pattern: from the tips of the five cusps emerge strong wrinkles, which practically meet in one central point.

The jaw, which formerly has been regarded by the author as a female jaw of *Meganthropus*, has been mentioned by Weidenreich (1945) who however, left the question open, whether the jaw would belong to a hominid or an anthropoid.

(*c*) *Meganthropus palaeojavanicus* v. Koenigswald

Large teeth with hominid affinities have been found since 1936, but it was only in 1941 that a large mandible was proof that we are here really dealing with a giant hominid. The jaw, the fragment of a mandible, is not inferior in size to a gorilla's jaw. That it is human is evident from the high position of the large foramen mentale on the outer, and from the high position of the foramen supraspinosum on the inner side, and the clearly indicated mental spine. The canine is small and, according to an isolated specimen, in no way different from the canine of modern man, except for the size. The first lower premolar is shaped as in *Sinanthropus*. The molar has a trigonid crest, which is a very primitive characteristic, as is the occurrence of a paraconid in the last deciduous molar.

This giant form shows so many primitive characteristics, that it cannot be regarded as a mere sidebranch of mankind, but must be placed within the line leading to modern man.

The occurrence of three different types of man in the Lower Pleistocene is very puzzling, as there is no indication that they occur in separate horizons. The analysis of the Javanese fauna shows, that the Pliocene faunas are closely related to those from the Indian Siwaliks, while just in the Djetis fauna, in the beginning of the Pleistocene there are certain elements (orang, gibbons, tapir, malayan bear) which originated in China. So we have reason to suppose that both regions had already their own form of hominids which, due to migrations, came together in Java.

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DISCUSSION

L. S. B. LEAKEY asked whether the author would amplify his remarks by stating whether he agreed that the *Sinanthropus* beds in China as well as the Trinil beds in Java were Middle Pleistocene, and later than the beds which had yielded the new Java human remains, equated with Villafranchian.

In reply, G. H. R. VON KOENIGSWALD said that the Chou-Kou-Tien layers had to be correlated with the Trinil beds of Central Java and, together with the Boulder Conglomerate of India, belonged to the early Middle Pleistocene.

THE LOWER LIMIT OF THE PLEISTOCENE IN AFRICA

By L. S. B. LEAKEY
Kenya

ABSTRACT

With the great increase of research all over the African Continent on the problems of the Stone Age in relation to geology and to fossil fauna, the need to have a clear definition of the Plio-Pleistocene boundary become urgent. Workers in different parts of the Continent are using different criteria, resulting in considerable confusion. A clear definition is also needed in order to make correlation between Africa and different parts of the world feasible. In Africa the problem is complicated by the fact that many mammalian genera normally regarded as typical of the Pliocene survived well into the Pleistocene.

The first Pan-African Congress on Prehistory, in January, 1947, resolved, on the advice of its Geological Committee, to use the terms Kageran, Kamasian and Gamblian to represent the Lower, Middle and Upper divisions of the Pleistocene, with the beginning of the Kageran period representing the Plio-Pleistocene boundary.

It is suggested that the Kamasian should be divided, and the Upper Kamasian given a distinctive name; the reasons for this suggested division are both geological and faunal.

The mammalian fauna of the Kageran in East Africa seems to correspond broadly with that of the Villafranchian in North Africa and Europe. It includes many genera which might normally be regarded as Pliocene, but also contains more evolved genera, including true elephants. It is therefore suggested that the Villafranchian of Europe and North Africa be regarded as the equivalent of the Kageran in East, Central and South Africa: and that the Villafranchian be regarded as the first stage of the Pleistocene, with the Plio-Pleistocene boundary immediately anterior to it.

INTRODUCTION

In recent years there has been a notable increase in the interest taken in the study of Early Man in the African continent, as was clearly shown by the success of the first Pan-African Congress on Prehistory in January, 1947. This interest is not confined to prehistorians, but geologists throughout the African continent are now also playing their part in the study of Early Man and his environment.

In Africa, a very great deal of the evidence of prehistoric man is to be found *in situ* in geological deposits, so that the geological aspects of the problem loom large; at the same time many important and interesting geological problems, such as the formation of the Gorge at the Victoria Falls on the Zambesi, or the age of the Kalahari sands depend in part at least for their solution on the study of Prehistory.

The lack of a clear, practical definition of the terms Pliocene and Pleistocene and of the Plio-Pleistocene boundary is causing increasing confusion for two reasons.

In some cases workers adopt and use entirely different definitions of these words, so that deposits which one scientist would call Lower Pleistocene are labelled Middle Pleistocene by another. In other cases, even if the same definition is adopted, it may be interpreted differently owing to the definition being difficult to apply, with the result that confusion again arises.

With the great increase in work on the Quaternary which is now going on in various parts of Africa, it has become a matter of urgency to decide on and accept one single definition, which must be so clear as to be incapable of diverse interpretation. Only in this way will comparison and correlation of the work done in different areas of Africa become possible.

Moreover, it is very necessary to be able to compare the results of work in Africa with that undertaken in other continents (and more especially Europe and Asia), so that the definition must not be one which is only applicable to Africa, but which has a wider application. Similarly, any definition which is considered as possible for Europe and/or Asia must also be discussed from the point of view of Africa and only be adopted if its use is possible in Africa.

CLIMATIC CHANGES IN EAST AFRICA	TYPICAL SITES FOR EVIDENCE	EAST AFRICAN CULTURE SEQUENCE			EAST AFRICAN FAUNAS	ZEUNER'S CLIMATIC STAGES IN EUROPE	THE CLASSICAL ALPINE SUCCESSION	EUROPEAN CULTURE SEQUENCE ACCORDING TO ZEUNER		
NAKURAN 2nd Post-Pluvial Wet Phase MAKALIAN 1st Post-Pluvial Wet Phase	MESOLITHIC AND NEOLITHIC									
1st Post-Pluvial Dry Phase	Deighton's Cliff etc.		Magosian							
GAMBLIAN 4th Pluvial 3 recession 2 recession 1	Enderit Drift. Malewa Gorge, Gamble's Cave, Yala River Muguruk etc.	Upper Kenya Capsian C Upper Kenya Capsian B Upper Kenya Capsian A Lower Kenya Capsian	Final Stillbay Stillbay Proto-Stillbay Developed Levallois	Upper Sangoan Middle Sangoan Lower Sangoan	Mainly as today but with some extinct species such as <u>Equus hollisi</u>, <u>Bubalus nilsoni</u>, <u>Proconsuloides naivashae</u> etc.	L.Gl. III L.Gl. II L.Gl. I	Würm Glacial 3 2 1		Mousterian Final Levallois	Magdelenian Solutrean Upper Aurignacian Middle Aurignacian Lower Aurignacian
3rd Interpluvial	Major unconformities everywhere between foregoing and later beds.	Kenya Fauresmith	Early Levallois	Lower Sangoan	Fauna very scarce The majority of the species of the earlier period become extinct as they do not reappear in next series of deposits.	L.Igl.	Riss-Würm Interglacial	Micoquian Upper Acheulean	Mousterian Middle Levallois Tayacian	.
KANJERAN 3rd Pluvial (Formerly called Upper Kamasian) 2 -recession- 1	Olduvai Upper part of Bed IV and upper part of Olorgesailie etc. Olduvai. Minor Red Bed in Bed IV & Red Bed at Olorgesailie Olduvai Lower part of Bed IV & Kanjera etc.	Early Fauresmith 6 Acheulean stages of the Chelles-Acheul culture 5 4 3 2 1	Pseudo-Stillbay Early flake culture (Kenya Hopefountain)	Early Sangoan Proto-Sangoan	<u>Palaeoloxodon antiquus</u>. <u>Pelorovis</u>. <u>Bularchus</u>. <u>Notochoerus</u>. <u>Hippopotamus gorgops</u>. <u>Sivatherium</u>. Giraffe. <u>Phacochoerus</u>. <u>Afrochoerus</u>. <u>Simopithecus</u>. <u>Papio</u>, etc etc.	P.Gl. II P.Gl. I	Riss Glacial	Middle Acheulean	Middle Levallois Early Levallois	
2nd. Interpluvial	Rawi Fish Beds Olduvia Bed III	Acheulean Stage 1 of the Chelles-Acheul culture			Fauna scarce. Many genera found earlier become extinct, including <u>Deinotherium</u>, <u>Archidiskodon</u>, <u>Schizotherium</u> etc & many fish die out	P. Igl.	Mindel-Riss Interglacial	Middle Acheulean Lower Acheulean	Clactonian II	
KAMASIAN 2nd Pluvial (Formerly called Lower Kamasian)	Olduvai Bed II and Lower Rawi Beds Olduvai Bed I and Laetolil	Chellean stages of the Chelles-Acheul culture 5 4 3 2 1 Oldowan			<u>Deinotherium</u>. <u>Archidiskodon</u>. <u>Schizotherium</u>. <u>Palaeoloxodon</u>. <u>Stylohipparion</u> <u>Sivatherium</u>. <u>Pelorovis</u>. <u>Bularchus</u>. <u>Notochoerus</u>. <u>Simopithecus</u>. <u>Equus</u>. <u>Hippopotamus gorgops</u> etc.	Apl. Gl. II Apl. Gl. I	Mindel Glacial			
1st Interpluvial	Kaiso and Marsabit	Oldowan			As below, but with <u>Palaeoloxodon</u> appearing and some of the earlier forms such as <u>Anancus</u> dying out.	Apl. Igl.	Günz-Mindel Interglacial	Abbevillian	Clactonian I	
KAGERAN 1st. Pluvial	Kanam Omo Kagera River	Early Oldowan Advanced Kafuan Early Kafuan			<u>Archidiskodon</u>. <u>Anancus</u>. <u>Deinotherium</u>. <u>Stegodon</u>. <u>Sivatherium</u>. <u>Stylohipparion</u>. <u>Gerontochoerus</u>. <u>Pro-notochoerus</u>. <u>Hippopotamus protamphibi</u> etc	E.Gl. II E.Gl. I	Günz Glacial	Cromerian Norvician Ipswichian		.
THE PLIO—PLEISTOCENE BOUNDARY										

FIG. 1.

[*Correction.* In the list of the East African Kageran fauna, for *Hippopotamus protamphibi* read *Hippopotamus protamphibius.*]

There are clearly several possible lines of approach to the problem of drawing up a definition for the Pleistocene and for defining the lower limit of this period, and while any one of these by themselves might be valuable, if a reasonable combination of two or more of them can be found, it would be still more valuable.

The principal possible methods by which a definition of the lower limit of the Pleistocene can be reached would seem to be:—

(1) Purely geological, with special reference to stratigraphy, raised marine beaches and terraces.
(2) Palaeontological, with particular reference to vertebrate rather than invertebrate fossils.
(3) Cultural, by reference to the Stone Age cultures found in geological deposits, with special reference to the appearance of new elements.

Let us consider the various lines of approach with respect to the African continent.

Taking first the purely geological approach, in Africa this is not at all easy, for the problem of the raised marine beaches has not yet been studied in any detail (although potentially it has great possibilities), and the study of Pleistocene deposits and their general stratigraphy is also in its infancy. Deposits laid down under alternating pluvial and interpluvial conditions have been studied to some extent, but there is as yet no means of being certain that pluvial conditions in, for example, North Africa, coincided with pluvial conditions in the equatorial belt, so that even if a good sequence is worked out in two different areas, correlation is not possible on purely geological grounds.

When palaeontological evidence is combined with the geological evidence, however, the position becomes more satisfactory. Let us therefore next consider the palaeontological approach in Africa.

I have stressed that in any approach of this sort it is the vertebrate rather than the invertebrate fossils that must be considered. This is due to the fact that the invertebrates have proved to be very misleading. One example will suffice to show this. The mollusca from the Kaiso fossil beds, which the mammalian fauna showed to be Pleistocene, included a high proportion of extinct species, while the mollusca from the Karungu fossil beds, of known Lower Miocene age, are said to be nearly all indistinguishable from living species.

But if the use of invertebrate fossils for dating purposes is impossible in Africa, the use of vertebrates is also not without its dangers.

It is now well known that in Africa the conditions for survival were particularly good, so that there are many instances of animals, which in Europe became extinct before the Pleistocene, surviving well into the Middle Pleistocene. For example, *Deinotherium*, *Chalichotherium* and *Hipparion*, which are all in Europe regarded as Pliocene forms, appear in Africa in deposits of Middle Pleistocene date. But if this fact is kept in mind, and if only total fossil assemblages are considered and not only individual species, then vertebrate fossils do seem to hold out a good prospect of being valuable for dating purposes.

Palaeontologists such as Arambourg and Dietrich believe that along this line good correlations are possible, and I agree with them wholeheartedly.

The chief obstacle to the use of Palaeontology alone for defining the Plio-Pleistocene boundary in Africa lies in the rarity of fossils in many parts of the continent due to unsuitable conditions for the preservation of bone. However, when good fossiliferous deposits do occur, it does seem that the mammalian fauna will prove useful. As an example, enough is now known to suggest that the fossil beds of Omo and Kanam are contemporary with the Villafranchian deposits of North Africa.

The third line of approach, through the Stone Age cultures found in different deposits, is in certain respects likely to prove of most use in Africa, with certain clearly defined cultural stages to be regarded as zone fossils.

Here again, great care has to be taken to use only complete assemblages of stone implements and not single specimens, for the tool types of one period often survive into a much later one. However, if any cultural assemblage is judged solely by its most advanced forms, important results can, I think, be obtained by the use of stone tools as zone fossils for dating purposes.

Pebble-tools of the primitive type known as Kafuan and Early Oldowan are sometimes found in association with much later tool types, but where they occur alone they can be regarded as zone fossils. Similarly, hand-axes where they occur in a true Chelles-Acheul assemblage can be regarded as zone fossils, although the type can also be found in other assemblages (such as the Upper Sangoan) of much later date.

Crescents and backed blades can also be used as zone fossils and their presence in any deposit can be regarded as showing that the deposit is not older than the Upper Pleistocene.

Now, while each of the three possible lines of approach has possibilities by itself, a combination of all three should—and in fact does—make correlations over wide areas possible, and go a long way to help define the lower limit of the Pleistocene.

Although it will be rare to find sites where all three lines of approach can be used together, their combined use will in most cases help to solve the problem of determining the age of any deposit that falls within the Pleistocene. It is therefore suggested that any definition of the lower limit of the Pleistocene should be drawn up in such a way that evidence derived from any of these three lines of approach can be brought into play.

So far as Africa is concerned, if the Plio-Pleistocene boundary is drawn immediately below the Villafranchian, it would probably be satisfactory. This would in effect mean that any deposit with a mammalian fauna comparable to the Villafranchian would be regarded as Lower Pleistocene.

Since we know that the primitive pebble cultures such as the Kafuan belong with such a fauna they could equally be used as a zone fossil for the Lower Pleistocene where fossil vertebrate remains were lacking. Similarly, any deposits lacking both fauna and culture but which by stratigraphical and general geological evidence could be shown to be the same age as other deposits containing either a Villafranchian fauna or an Early Oldowan type of culture could be regarded as Lower Pleistocene.

At the first Pan-African Congress on Prehistory it was decided, on the advice of the geological committee, to use certain divisions of the Pleistocene already worked out in East Africa throughout the whole continent. The terms adopted were Kageran for the Lower Pleistocene, Kamasian for the Middle Pleistocene and Gamblian for the Upper Pleistocene. These divisions are regarded as valuable because each is capable of being distinguished either on faunal or cultural grounds and the lower limit of the Kageran is thus to be regarded as the Plio-Pleistocene boundary, if the resolution is adhered to. This fits perfectly with the views advanced in this paper; for the fauna of the Kageran is essentially comparable to the Villafranchian and the culture of the Kageran is essentially the primitive Kafuan and Early Oldowan.

There is one point, however, that should be mentioned here. The term Kamasian as adopted for the Middle Pleistocene needs revision. That part of the division which was formerly called the Upper Kamasian should be given a new name. There is good faunal, cultural and geological evidence to justify the division of the Kamasian into two distinct stages.*

*This matter was discussed by the author at a meeting of the *Association des Services Géologiques Africains* in August—when the resolution of the Pan-African Congress came up for examination. (See Part XIV of this Report.)

THE PLIOCENE-PLEISTOCENE BOUNDARY IN ITALY

By CARLO I. MIGLIORINI

Italy

ABSTRACT

In Italy the record of the pertinent mammalian faunistic sequence is too defective in its lower section to be utilized for establishing the Pliocene-Pleistocene boundary. Recourse must therefore be made to the marine sequence, which in any case would appear to be the best procedure. In this sequence the alternative lies in placing the boundary between the Plaisancian-Astian and the Calabrian, or between the latter and the Sicilian. All these formations have much the same facies.

After reviewing recently obtained data, preference is given to the first solution for the following reasons:

(1) The Calabrian is readily distinguishable palaeontologically from the Plaisancian-Astian, but not from the Sicilian.

(2) An important mountain-building phase took place in the Apennine region between the Plaisancian-Astian and the Calabrian, while no such event occurred between the latter and the Sicilian.

(3) Fossil faunas and floras afford good evidence that between the Plaisancian-Astian and the Calabrian there was a pronounced climatic cooling which should herald the Ice Age: evidence of a further cooling between the Calabrian and the Sicilian is doubtful.

I. INTRODUCTION

1. Since geological time units are mere conventions introduced for effecting and expressing correlation, it is desirable that every stratigraphical boundary should be (i) readily identifiable in the field and (ii) (from the base of the Cambrian upwards) unequivocally distinguishable palaeontologically over as wide an area as possible. That it is also desirable that boundaries should split up gological time into balanced subdivisions has no bearing upon the Pliocene-Pleistocene problem, since the difference in time implied by the various solutions proposed is practically negligible by the geological clock.

Features enabling requirements (i) and (ii) to be fulfilled in a truly widespread manner can clearly be brought about only by marked changes of environment that are correspondingly widespread; consequently a boundary established on the above practical criteria will also be satisfactory from a purely theoretical point of view.

2. Perhaps no stratigraphical boundary fully satisfies requirements (i) and (ii) the world over. Even major events in geological history did not affect sedimentation appreciably and simultaneously everywhere; moreover, the sequence in which a boundary falls may be unfossiliferous or not significantly fossiliferous. To these intrinsic sources of imperfection, another may be added arising from the very manner in which boundaries were successively introduced as knowledge progressed; and thus were usually established prematurely, before geological exploration was extended enough to warrant a judgment of the geographical range of applicability of criteria (i) and (ii).

3. From the above remarks it follows that it may be considered as not wholly unfortunate that the Pliocene-Pleistocene boundary has not yet been rigorously established, since to-day there are far more data enabling one to do so satisfactorily than there were in the past.

To comply as fully as possible with the two requirements specified in ¶ 1, boundaries should obviously be established after considering the conditions affecting them in as many countries as possible. And it would appear that the best procedure would be to collect contributions on the subject dealing with different countries, and to submit them to a suitable international committee to decide upon the matter on the strength of the data submitted and of the relative importance of the development of the Pliocene and Pleistocene in the various countries concerned.

In accordance with these views, this paper purports to deal summarily with the Pliocene-Pleistocene boundary in Italy only, without considering how the problem may stand in other countries. It may be added incidentally that the Pliocene and Pleistocene have long been known to be well represented in Italy by very fossiliferous formations—it was upon these that Lyell (1833) established the Pliocene

System; so that data concerning the most suitable position for placing the boundary between these two periods in Italy should carry some weight in a European or a more extensive ruling on the subject.

II. NECESSITY OF ESTABLISHING THE BOUNDARY ON THE MARINE SEQUENCE

4. Where there is the alternative of establishing a major stratigraphical boundary on a marine or on a continental sequence, it appears to the writer that preference should unhesitatingly be given to the former, owing to the generally more widespread and continuous development of marine formations and to the wider and readier diffusion of marine organisms.

The correlation of continental formations is usually difficult: continental invertebrate faunas are markedly provincial, and terrestrial vertebrates are too rare and too exacting in their environmental requirements to make good stratigraphical markers.

5. Apart from the above general considerations, moreover, vertebrates cannot be utilized in Italy for the determination of the Pliocene-Pleistocene boundary owing to the incompleteness of the record of their faunistic succession. Abundant mammalian remains have been found in Italian Villafranchian and later lacustrine and alluvial deposits; but only one species, *Tapirus arvernensis*, has so far been recorded in the continental formations immediately preceding the Villafranchian. Accordingly no palaeontological criteria are afforded by mammalian faunas for deciding whether the Pliocene-Pleistocene boundary should be placed at the commencement or at the end of the Villafranchian: these being —as shall presently be shown—the two alternative positions upon which the choice for such a placing must fall.

III. THE PLAISANCIAN-ASTIAN, THE CALABRIAN, AND THE SICILIAN SERIES

6. For those who are not conversant with Mediterranean marine Pliocene and Pleistocene sequences, the following summary of stratigraphical data will save the trouble of consulting a textbook.

All agree in assigning to the Pliocene the *Plaisancian* clays and the overlying *Astian* sands. Following Gignoux's views (1943, p. 528), these formations are not interpreted as true stages, as at one time was customary, but merely as facies; the latter laid down in coastal waters, and the former farther off-shore. The two formations may therefore be referred to collectively as the *Plaisancian-Astian.*

Where the Plaisancian-Astian does not close the marine sedimentation, it is followed by the *Calabrian*, which has much the same facies, but is distinguishable palaeontologically: it is considered to be the marine equivalent of the continental *Villafranchian.*

The Calabrian, in its turn, is sometimes followed by the *Sicilian*, which is concordantly assigned to the Pleistocene, and often held to be contemporary with the Günz or Mindel glaciations. The Sicilian occurs in terraces: lithologically it resembles the Plaisancian-Astian and the Calabrian.

From the above summary description it clearly follows that in Italy the problem of establishing the Pliocene-Pleistocene boundary lies in the alternative of placing it between the Plaisancian-Astian and the Calabrian, or between the latter and the Sicilian.

7. Unfortunately neither of these two horizons on which our choice must fall for the establishment of the Pliocene-Pleistocene boundary in Italy fulfils the first requisite specified in ¶1, which should consist in some constant and pronounced change of facies or in a marked unconformity. Concerning the lack of any change of facies, it may be added that—if certain discontinuous Pontian evaporite formations be excepted—the lithological features of Italian marine formations taken as a whole have not varied much from the Tortonian to the present day.

It is true, as will be explained later, that in Italy the boundaries between the Plaisancian-Astian and the Calabrian and between the latter and the Sicilian are occasionally revealed by stratigraphical relations, but this does not always apply. These boundaries, therefore, are essentially palaeontological.

8. The marine faunistic succession that gave rise to the original distinction into Plaisancian-Astian, Calabrian, and Sicilian was malacological and was briefly as follows:—

Plaisancian-Astian.—The bulk of the fauna still lives in the Mediterranean, and the remainder is made up of extinct forms and of others that to-day live off the Senegal coast. The fauna indicates warmer waters than those of the present Mediterranean.

Calabrian.—The percentage of living Mediterranean forms increases substantially. A few extinct forms survive from the Plaisancian-Astian and a small number of immigrants from colder waters make their appearance, the best known of which is *Cyprina islandica.*

Sicilian.—Nearly all the extinct forms disappear and the number of northern immigrants increases slightly. The percentage of living forms is higher than in the Calabrian.

9. The only abrupt change in the above faunistic succession is marked by the first appearance of northern immigrants between the Plaisancian-Astian and the Calabrian. It would therefore seem plausible to interpret this appearance as coinciding with the beginning of the Ice Age and to adopt it as the Pliocene-Pleistocene boundary; and this, in fact, is the view favoured to-day by most geologists, amongst whom may be mentioned Rovereto (1923–24, p. 210), Haug (1927, p. 1766), Blanc (1942, p. 211), di Napoli Alliata (1947) and, with more hesitation, Leonardi (1934).

Other geologists, however, favour placing the Pliocene-Pleistocene boundary between the Calabrian and the Sicilian. Amongst modern authors, Gignoux is the outstanding authority to hold this view, and his treatment of the problem must be outlined, since it has had considerable influence on the views of other geologists; which is only natural when Gignoux's great scientific authority and extensive first-hand knowledge of the Italian Pliocene and Pleistocene are considered.

10. Gignoux maintains that in Italy the Plaisancian-Astian and the Calabrian form part of the same sedimentary cycle and are therefore inseparable and should be both included in the Pliocene (Gignoux, 1943, p. 552). In the course of the extensive field-work that led to his fundamental memoir on the Pliocene and Pleistocene of southern Italy (Gignoux, 1913), Gignoux came across no exposure showing any evident sedimentary break between the Plaisancian-Astian and the Calabrian, and therefore was quite justified in placing both the formations in the same sedimentary cycle. It will presently be shown, however, that this argument of Gignoux's has been invalidated by more recently obtained data.

IV. THE BOUNDARY BETWEEN THE PLAISANCIAN-ASTIAN AND THE CALABRIAN

(*a*) *Palaeontological and climatic differences between the Plaisancian-Astian and the Calabrian*

11. The features of the mollusc fauna that enable the Calabrian to be distinguished from the Plaisancian-Astian have already been briefly enumerated (¶8). Here it need only be emphasized that even when a moderate number of molluscan forms is available there is no difficulty in establishing which one of the two series one is dealing with.

12. In recent years it has been found that the boundary between the Plaisancian-Astian and the Calabrian is also well defined by the foraminifera. This is mainly due to the work carried out by di Napoli Alliata, who made a special study of the question first in the Plaisancian-Astian and later formations outcropping in Sicily (di Napoli Alliata, 1937, Palermo and Roma; Trevisan, 1938), and more recently in those of the subsurface of the Po plain, whence he examined a great number of cores from exploration wells (di Napoli Alliata, 1946 " Esame " and " Contributo," and 1947). In both instances the microforaminiferal associations in the two series are very distinct. Thus, according to di Napoli Alliata (1946, " Contributo "), the cores from a well in the Rovigo district show that only about 50 per cent of the forms of the local Plaisancian foraminiferal fauna continue into the Calabrian, and even these with a markedly different frequency. The two microfaunas, moreover, exhibit the following significant quantitative differences:—

	Plaisancian per cent		*Calabrian* per cent
Extinct forms	12·5	...	4
Forms still living, but not in the Mediterranean	6·7	...	11·4
Forms living in cold seas	none	...	8·7
Forms not recorded in formations older than the Calabrian	—	...	4

13. From the above figures it follows that the proportion of cold sea forms appearing in the Calabrian is considerable and amounts to nearly 9 per cent (13 in a foraminiferal fauna of 149 species

and varieties). Another indication of cooling in the Calabrian is afforded by the appearance in shallow water deposits of foraminiferal associations that to-day inhabit colder waters at considerable depth in the Mediterranean (di Napoli Alliata, 1946, vol. 52).

14. Di Napoli Alliata (1947) also remarks that the marine Calabrian in the subsurface of the Po plain near Lodi (S.E. of Milan) contains pollen of *Alnus*, *Pinus*, *Abies*, *Castanea*, *Ericaceae* and ferns denoting a cold temperate climate, while the Pliocene climate in Italy was considerably warmer than to-day's.

Good evidence of the climatic cooling in the Calabrian is also afforded by the floras of the Valdarno Superiore lake deposits, in the Arno valley above Florence. Recent work by Merla (in the press), carried out in connection with prospection for lignite, has borne out Sestini's (1936) view that the lake whose sediments contain the well-known Valdarno Superiore Villafranchian mammalian fauna was preceded by an older one, in whose deposits the only vertebrate found so far is *Tapirus arvernensis*. The pollen and other plant remains of the Villafranchian lake include *Abies*, *Picea*, *Pinus*, *Fagus*, *Alnus*, *Tilia* and indicate a climate perceptibly cooler than to-day's; while the older lake deposits, upon which the Villafranchian ones were laid down without any sedimentary break, contain remains of *Sequoia*, *Taxodium*, *Glyptostrobus*, *Alnus*, *Fagus*, *Quercus*, *Platanus*, *Liquidambar*, *Laurus*, *Cinnamomun*, *Magnolia*, *Acer*, *Juglans*, *Pterocarya*, *Cassis*, thus indicating a climate appreciably warmer than to-day's.

(*b*) *Transgressive situation of the Calabrian*

15. The transgressive situation of the Calabrian in Sicily was remarked as far back as 1889 by De Stefani, and sporadically in later years by other authors; but Trevisan (1938) was the first to recognize that this condition prevailed all over the island except around Messina.

On the Italian mainland, not much detailed work has been done on the Plaisancian-Astian and Calabrian which outcrop extensively along the Apennine foothills. No true unconformity is perceptible between the two formations in Calabria (Ruggieri, 1944; Trevisan, 1942) or in the Imola district S.E. of Bologna (Ruggieri, 1944). In the foothills fringing the southern edge of the Po plain in the Modena district, on the other hand, a disconformity between the Plaisancian-Astian and the Calabrian has recently been reported by Montanaro Gallitelli (1947).

The conditions prevailing in the subsurface of the Po plain are fairly well known. Di Napoli Alliata (1946, " Contributo ") has recently described how the microfauna shows that in the subsurface of the Rovigo district—in the eastern section of the plain—the base of the Calabrian corresponds to a sudden and pronounced shallowing, followed by deepening and then again by shallowing. The same author remarks that this sequence should be interpreted as evidence of a complete Calabrian sedimentary cycle; and adds that a sudden shallowing of the sea at the base of the Calabrian has been found to occur in the subsurface of the Po plain not only in the Rovigo district, but in several other areas as well. Much the same conditions prevail as far west as Lodi and S. Colombano al Lambro, S.E. of Milan.

There are thus several concurring lines of direct evidence showing that in Italy the boundary between the Plaisancian-Astian and the Calabrian is of a transgressive nature; but from this it obviously does not follow that the boundary should everywhere be marked by a true disconformity or by a perceptible difference of facies. All evidence of any transgression, no matter how important, must necessarily cease when a sufficient depth and a sufficient distance from the shore are reached.

16. The commonly transgressive nature of the relations between the Plaisancian-Astian and the Calabrian in Italy is in keeping with the course of the local mountain-building, since an energetic orogenic phase occurred at this very time all over the Apennines.

This is especially apparent in southern Italy. Along the Apennine foothills on the Adriatic and Ionian slope to the south and south-west of Foggia the Plaisancian-Astian is bent into recumbent folds: as in the Cervaro Valley, at Candela, and between the town of Melfi and the Ofanto river; while the Villafranchian deposits lying farther eastward and those in old lacustrine basins within the

adjoining Apennine ranges are practically flat-lying. To the east of Sala Consilina (about 120 km. S.E. of Naples), the actual watershed of the Apennines, here consisting in an upfaulted " horst " of Mesozoic and Lower Tertiary limestones, is capped by a marine Plaisancian-Astian outlier lying at about 1,150 m. above sea-level; while at the foot of the step fault-scarps on either side of the " horst " three basins occur which once harboured Villafranchian lakes, whose deposits attain heights ranging from 650 to 800 m. above sea-level (Migliorini, 1947).

In the Central and Northern Apennines the evidence of the orogenic phase at the close of the Plaisancian-Astian is not so striking; but that the phase was also felt in these areas is shown by the widespread occurrence within the Apennines of large basins of obviously tectonic origin which harboured Villafranchian lakes. These basins are spread along the Apennine mountain arc through a distance of some 650 km., from the Magra valley, north of Spezia, to the valley of the Mercure, in the southernmost extremity of the Basilicata region.*

V. THE BOUNDARY BETWEEN THE CALABRIAN AND THE SICILIAN

(*a*) *Palaeontological and climatic differences between the Calabrian and the Sicilian*

17. Up to recent times the palaeontological distinction between the Calabrian and the Sicilian outlined in ¶8 went quite unchallenged. It rested admittedly on a qualified difference only, since it consisted in a mere accentuation of the features which distinguish the Calabrian from the Plaisancian-Astian faunas, and was not marked by the sudden appearance or disappearance of any considerable group of species.

Research carried out in the last few years, however, has so reduced even this qualified faunistic difference between the Calabrian and the Sicilian as to render it practically evanescent. Molluscan forms that were thought to have died out with the Calabrian are being found to have survived into the Sicilian, while living Mediterranean and cold water forms which were thought to have made their first appearance in the Sicilian are being found in the Calabrian. This knowledge has accrued especially from work carried out by Tamajo (1937), by Trevisan and di Napoli Alliata (1938), and by T. De Stefani (1942) in Sicily, and by Ruggieri (1944) in the foothills of the Apennines in the Imola district.

18. To the best of the writer's knowledge, the relations between the Calabrian and the Sicilian foraminiferal faunas have not yet been satisfactorily established. Recently di Napoli Alliata (1947) has dealt with the foraminifera from a formation that he considers Sicilian overlying the Calabrian in the subsurface of the Lodi district in the Po plain, and concludes that this microfauna tends to indicate a rise of temperature. This would seem to be at variance with the currently accepted views on Quaternary climates (¶6, 8, and 9).

19. The slight faunistic differences that were originally held to exist between the Calabrian and the Sicilian would only have implied the further cooling of an already cold climate. But since recent research is showing that these differences are even slighter than they were thought to be, it is doubtful whether any cooling at all took place.

(*b*) *Stratigraphical relations*

20. Both in Sicily and on the Italian mainland, the deposits that are unquestionably of Sicilian age occur as terraces lying on the Calabrian, at times with a slight disconformity. But this distinctive relationship is probably unavoidable, in so far as it would seem to be the only feature specifically distinguishing the Sicilian from the Calabrian: from what has been said concerning the great faunistic resemblance between the two formations, it follows that in deposits laid down far enough off-shore to show no direct or indirect signs of disconformity, the two series would be very difficult, if not impossible, to differentiate.

* A map of the Villafranchian lakes in the northern and central Apennines has been compiled by Merla (1940). A similar map, covering all the Apennines but based on older data, was published by Sacco (1919) and is reproduced by Gignoux (1943, p. 553): in the latter the Villafranchian is indicated as " Pliocene lacustre".

21. Between the Calabrian and the Sicilian no orogenic phase occurred in the Apennine region in any way comparable with the one between the Plaisancian-Astian and the Calabrian. The Villafranchian lake deposits within the Apennines (¶16) only show occasional minor tilting and faulting evincing incomparably milder mountain-building activity than that which at the close of the Plaisancian-Astian produced the basins that harboured the lakes.

VI. SUMMARY AND CONCLUSIONS

22. (*a*) In Italy the problem of establishing the Pliocene-Pleistocene boundary rests with the alternative of placing it between the Plaisancian-Astian and the Calabrian, or between the latter and the Sicilian (¶6).

(*b*) The Calabrian is satisfactorily distinguishable palaeontologically from the Plaisancian-Astian both by means of its molluscs and its foraminifera (¶8, 11, 12).

The faunistic differences between the Calabrian and the Sicilian are very slight, and recent research is showing that they are even slighter than they were thought to be (¶8, 17, 18).

(*c*) The Calabrian is often distinctly unconformable with the Plaisancian-Astian and, where it is not so, it sometimes shows some signs of transgression (¶15). Important mountain-building events took place in the Apennine Region between the Plaisancian-Astian and the Calabrian (¶16).

Formations recognized as Sicilian occur as terraces on the Calabrian. But it does not follow that such relations are constant, since Calabrian and Sicilian deposits occurring in a continuous sedimentary sequence would probably be palaeontologically and lithologically undistinguishable (¶20, 6). No important mountain-building phase took place in the Apennine Region between the Calabrian and the Sicilian (¶21).

(*d*) The malacological and foraminiferal faunas and the flora concur in indicating that a pronounced climatic cooling took place between the Plaisancian-Astian and the Calabrian, which may be taken to mark the setting in of the Ice Age (¶13, 14).

Some further cooling may have occurred between the Calabrian and the Sicilian, but evidence on this point is very doubtful (¶19).

23. The above points clearly lead to the conclusion that in Italy it is preferable to place the Pliocene-Pleistocene boundary between the Plaisancian-Astian and the Calabrian rather than between the latter and the Sicilian.

By so doing

(i) it is possible to establish the Pliocene or Pleistocene age of any reasonably fossiliferous marine outcrop, even if it is quite isolated;

(ii) the Pliocene-Pleistocene boundary is made to correspond with an important phase of Apennine mountain-building activity, and

(iii) with a pronounced climatic cooling which may be taken to coincide with the setting in of the Ice Age, and therefore to be widespread enough to favour distant correlation with marine formations outside Italy.

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VILLAFRANCHIAN STRATIGRAPHY IN SOUTHERN AND SOUTH-WESTERN EUROPE

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ABSTRACT

The deposits containing the classic Villafranchian fauna in Italy (Po Valley, Upper and Lower Arno Valley, and elsewhere in the Peninsula), the Saône Valley of Eastern France, and the Puy-en-Velay Basin (Haute-Loire) of Central France not only consistently overlie sediments laid down during Astian times, but also they are in turn immediately overlain by horizons that clearly belong to the First Interglacial (Cromer Forest-Bed/Saint-Prestian) Stage. With the exception of Peninsular Italy, where a marine regime was still under way, the beds in question, which are of continental facies and which are considered as belonging to a Villafranchian Stage, represent a comparatively sudden break in the long sedimentary cycle that had prevailed in southern and south-western Europe throughout Middle (Plaisancian) and Upper (Astian) Pliocene times. During the Villafranchian Stage, a marked lowering of the temperature occurred, which is consistent with the view that the deposits laid down at this time were accumulated under the conditions of glaciation in Northern Europe, the Alps, and the Pyrenees. Therefore, the Villafranchian Stage marks the base of the Pleistocene and should not be retained in the Pliocene.

HOMINIDAE IN RELATION TO THE PLIOCENE-PLEISTOCENE BOUNDARY

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ABSTRACT

Evidence to hand does not appear to justify the assumption that the Haug line (entry of *Elephas*, *Bos* and *Equus*) coincides with the " Günz " glaciation. Cool-climate elements in the Villafranchian biota may correspond with the Donau stages of glaciation in the Alps. Almost one third of the Pleistocene period as defined by Haug had elapsed before the Abbevillian (earliest Chellean) stage of culture had been reached in equatorial Africa, where its evolution from the Oldowan pebble-tool culture can be traced. In N.W. Africa Abbevillian tools have been reported from deposits contemporary with the Sicilian beach, which immediately antedated the marked recession of sea-level usually correlated with Günz. The time required for the diffusion of cultural tradition between central and northern Africa would be negligible on an early Pleistocene time-scale. Taking the spread of Abbevillian tradition in Africa as an approximate time-line, the beds in East Africa with pre-Abbevillian pebble-tools must considerably antedate the Sicilian stage. The Haug line should be accepted as providing a theoretical basis for the Pliocene-Pleistocene boundary, but with the clear recognition of the possibility that part of the Pleistocene thus defined will prove to be pre-Günzian.

The occurrence of pre-Abbevillian pebble-tools in association with mammalian fauna of Villafranchian equivalence, in the Kageran beds at Kanam (Kenya) and Kikagati (Uganda), suggests that *Homo* (s.1.) may qualify for inclusion with *Elephas*, *Bos* and *Equus* as among the theoretical markers of the Pliocene-Pleistocene boundary.

SOME REMARKS ON THE MARINE LOWER PLEISTOCENE OF THE NETHERLANDS

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ABSTRACT

In the west of the Netherlands the marine Lower Pleistocene (Icenian) occurs in considerable thickness (up to about 180 m—see sections). Towards the east it passes into continental deposits. In the centre of the basin there is continuous sedimentation during Amstelian and Icenian, elsewhere the Icenian covers Scaldisian or older deposits.

The Amstelian-Icenian boundary was assumed by Tesch to represent the Pliocene-Pleistocene boundary, on account of the molluscs. Ten Dam and Reinhold are of the same opinion on account of the foraminifera, though they observed an increase of cold water species already during the Amstelian. The second author has prepared statistical diagrams, in which finer fractions were also taken into account. In the record of the boring at The Hague, the increase of arctic species such as *Elphidiella arctica* is apparent in the Amstelian. Consequently, the authors are of opinion that the Pliocene-Pleistocene boundary should tentatively be placed at the base of the Amstelian. In the latter the increase of the lagoonal species *Streblus beccarii* points to a regression, which might be an indication of a glaciation.

THE western part of the Netherlands belongs to a sedimentary basin, in which the older Pleistocene and sometimes the Pliocene reach a considerable thickness. Below the coarse-grained sands and gravels, mostly correlated with the Riss glaciation, there are thick fluvial deposits, the middle part of which is again coarse-grained (stippled on the sections). They are provisionally indicated by the Netherlands Geological Survey as " Pre-Riss." Subdivisions of this deposit have been established in several regions by means of fossil mammals, pollen and sediment-petrology. Its thickness is between 70 and 100 m. in the S.W. of the country, becoming 140 and even 195 m. in borings near the centre.

Below the terrestrial " Pre-Rissian " follow marine deposits, which were formerly considered as Pliocene, till Tesch pointed out (in 1927) that the molluscs are those of a cold climate and are the same as those of the English Icenian as defined by Harmer in 1902 (non 1900). Tesch consequently proposed to place the Pliocene-Pleistocene boundary at the base of the Icenian, the latter being the equivalent of the Günz glaciation in the west of the Netherlands. It should be kept in mind, however, that the Icenian in the Netherlands does not necessarily comprise the whole of the English Icenian, which consists of the Norwich Crag, the Chillesford beds and the Weybourne Crag. On the contrary, the Weybourne zone, characterized by the sudden appearance of *Tellina balthica*, has been found by Tesch in one boring only (Schoorl); elsewhere the Dutch Icenian only corresponds to at most the former two zones and in many places to only part of these, the remainder of the Icenian being in fluvial facies. The marine Icenian has only been met with in borings and nowhere outcrops at the surface.

The foraminifera of the Dutch Icenian have been described by Reinhold and ten Dam. The foraminifera of the Icenian again demonstrate the cold character of the Icenian, the fauna consisting for the greater part of the two species *Elphidiella arctica* and *Streblus* (*Rotalia*) *beccarii*, the former of which is an arctic species. The Amstelian or Upper Pliocene on the other hand has a somewhat richer fauna, in which *Elphidiella arctica* already occurs, though less abundantly.

By means of the foraminifera it has been possible to distinguish the Icenian in most of the borings of the Netherlands. In the centre it covers the Amstelian; near the borders of the basin, however, the Amstelian appears to be lacking and the Icenian is underlain by Pliocene (Scaldisian) or even older parts of the Tertiary. The sections reproduced here show the considerable thickness of the Icenian in the central part of the country, especially in a median zone, whereas in the E. and the S. the thickness decreases and the marine strata are more and more replaced by fluvial deposits.

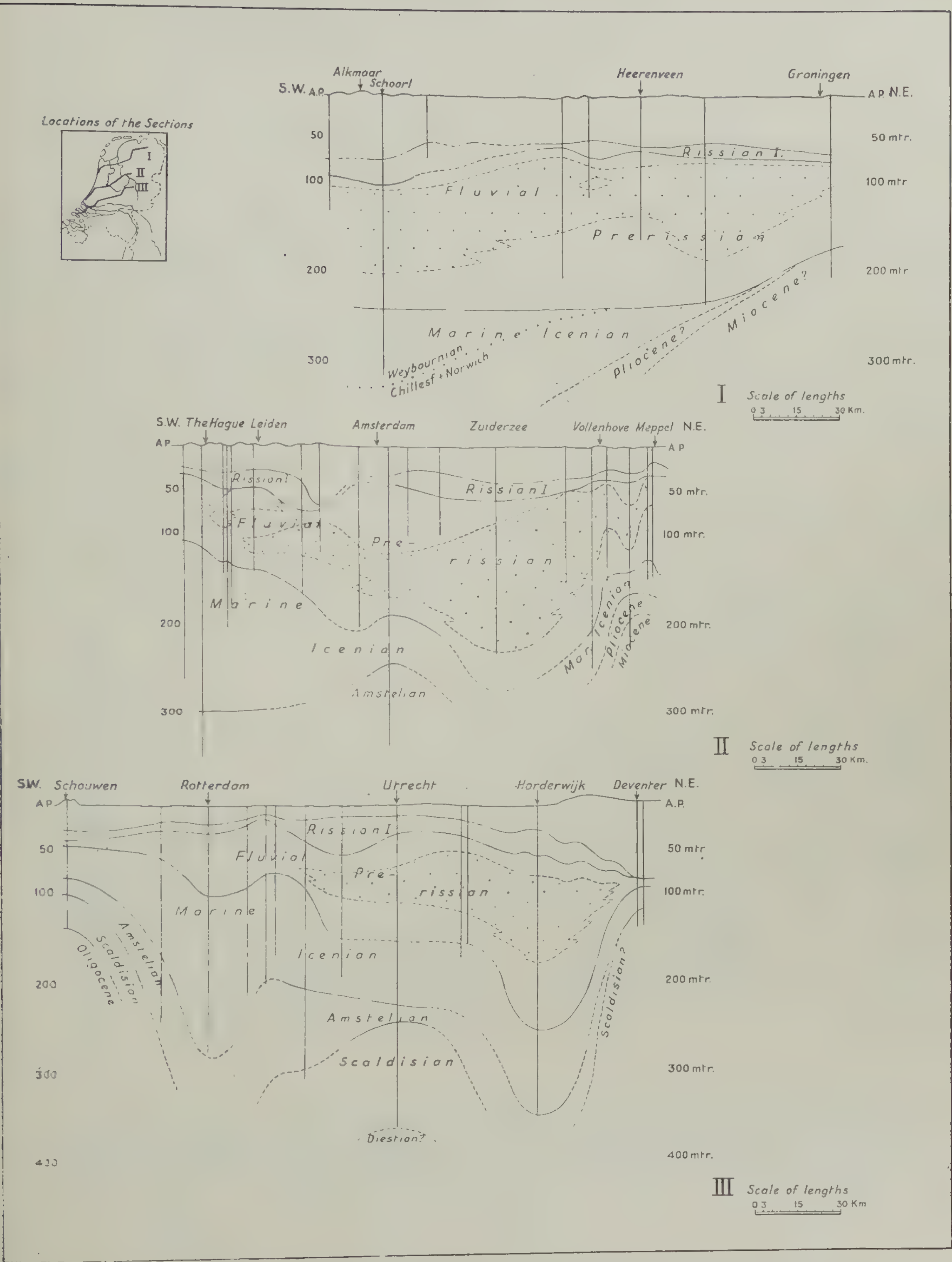

FIG. 1.—*Three Sections through the marine Lower Pleistocene of the Netherlands.*

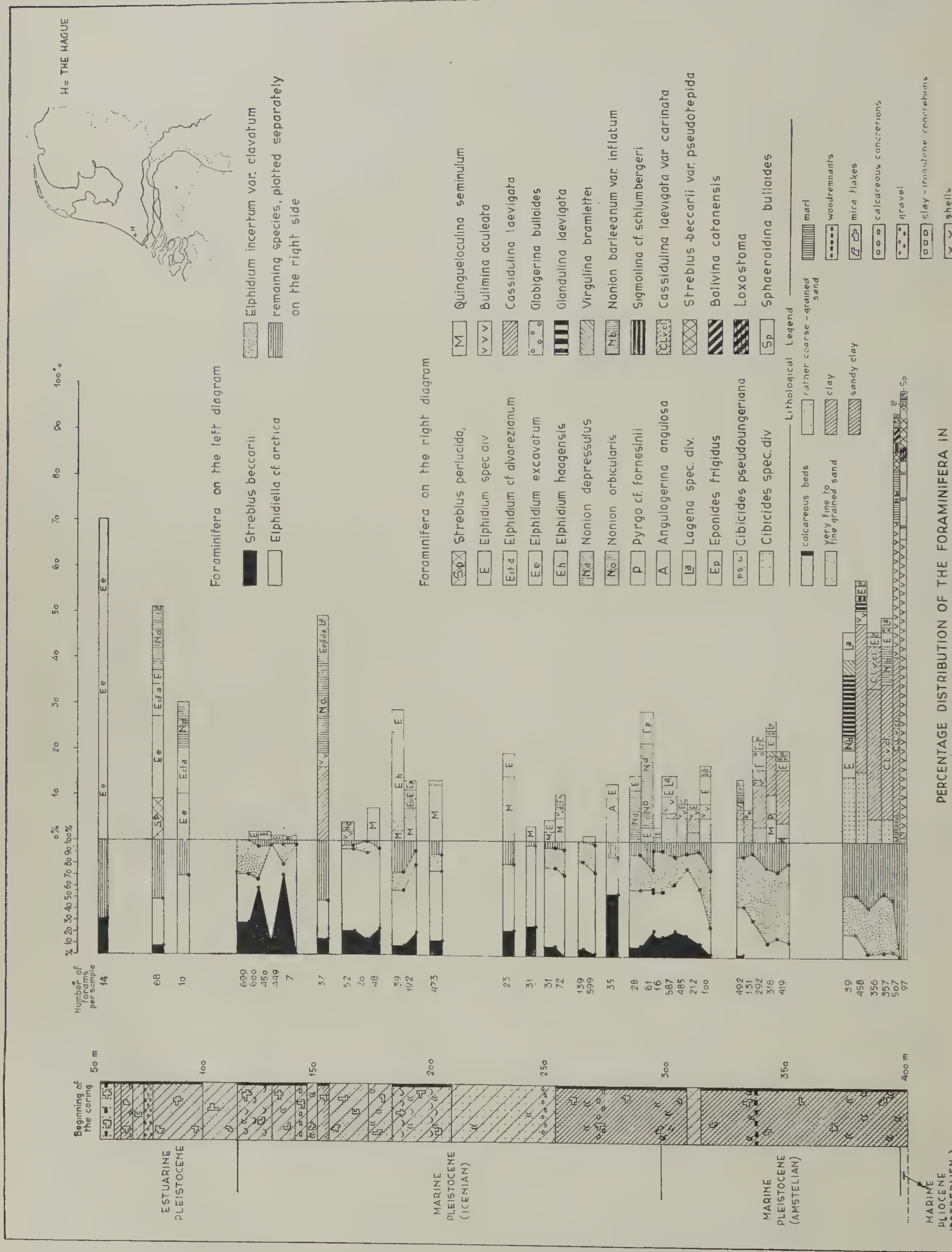
PERCENTAGE DISTRIBUTION OF THE FORAMINIFERA IN THE PLIO-PLEISTOCENE OF A BORING NEAR THE HAGUE
H = THE HAGUE
Beginning of the coring
ESTUARINE PLEISTOCENE
MARINE PLEISTOCENE (ICENIAN)
MARINE PLEISTOCENE (AMSTELIAN)
MARINE PLIOCENE (POEDERLIEN-SCALDISIEN)
Number of forams per sample
Foraminifera on the left diagram
Streblus beccarii
Elphidiella cf. arctica
Elphidium incertum var. clavatum
remaining species, plotted separately on the right side
Foraminifera on the right diagram
Streblus perlucida,
Elphidium spec div
Elphidium cf alvarezianum
Elphidium excavatum
Elphidium haagensis
Nonion depressulus
Nonion orbicularis
Pyrgo cf. fornasinii
Angulogerina angulosa
Lagena spec. div.
Eponides frigidus
Cibicides pseudoungeriana
Cibicides spec. div
Quinqueloculina seminulum
Bulimina aculeata
Cassidulina laevigata
Globigerina bulloides
Glandulina laevigata
Virgulina bramlettei
Nonion barleeanum var. inflatum
Sigmoilina cf. schlumbergeri
Cassidulina laevigata var carinata
Streblus beccarii var. pseudotepida
Bolivina catanensis
Loxostoma
Sphaeroidina bulloides
Lithological Legend
calcareous beds
very fine to fine grained sand
rather coarse-grained sand
clay
sandy clay
marl
woodremnants
mica flakes
calcareous concretions
gravel
clay-ironstone concretions
shells
shellfragments

FIG. 2.

The latest investigations of the second author have brought about some changes. As it appeared that some species, considered as typical for the Dutch Amstelian, as *e.g. Cibicides lobatulus* and *Quinqueloculina seminulum*, appeared again at some zones in the Icenian, he plotted the foraminiferal content of some borings in the form of statistical diagrams, showing the percentage distribution. The smaller fraction (0,3—0,14 mm.), which had been left out at first, was also included. This resulted in diagrams of the type of the one reproduced here from The Hague boring (Mient).

This boring was carried out in 1938 by the B.P.M. It passed not only through the Pliocene-Pleistocene boundary, but revealed also at least two disconformities, one between the Paleocene and the Middle Oligocene and one between the latter and the Middle Miocene(?).

From the diagram it appears that the arctic form *Elphidiella* cf. *arctica* appears at a depth of 395 m. and increases in number upwards. The other species show that the environment was still that of a deeper sea, in which we may assume cold streams that brought down *Elphidiella arctica*. Gradually, from about 330 m. upwards, *Streblus* (*Rotalia*) *beccarii*, a form typical for lagoonal conditions, makes its appearance. Judging from other species, as *e.g. Cassidulina laevigata*, these beds should still be reckoned to the Amstelian. Only at 295 m the latter species have disappeared and the fauna may now be called Icenian. Lagoonal species such as *Streblus beccarii* demonstrate its littoral character throughout the deposition of 180 m. of sediments, which can only be explained by assuming a subsidence of the sedimentary basin.

It appears from the diagram that the percentages of *Elphidiella arctica* and *Streblus beccarii* vary considerably during the Icenian, which fact should make us cautious about attaching too much weight to the percentages of these species in separate samples.

At the depth of 155 m. there again occur deep-water species, which were also observed in other borings, and which perhaps point to an acceleration of the subsidence. Thereafter a stronger regression sets in, apparent from the predominance of *Streblus beccarii*. From 114 m. upward the strata are no longer marine, though an occasional appearance of some brackish foraminifera points to the neighbourhood of the sea.

As to the Pliocene-Pleistocene boundary: from the diagram it appears that at the level assumed by Tesch as the Pliocene-Pleistocene boundary, viz. the base of the Icenian, there was not so much a climatological break, but rather a continuation of the regression which had already started in the Amstelian; this might be an indication of a glaciation. A climatological boundary might be situated deeper in the geological column, namely at the level where the arctic influence becomes visible through the appearance of cold water species as *Elphidiella* cf. *arctica* and *Eponides frigidus* near the base of the Amstelian. We tentatively propose to consider this level as the Pliocene-Pleistocene boundary, on condition that this should be in agreement with other evidence.

THE PLIO-PLEISTOCENE BOUNDARY IN THE NORTH-EASTERN COAST OF SPAIN

By J. M. RIBERA-FAIG

Spain

ABSTRACT

The study of the Pliocene and Pleistocene sequence in the north-eastern coast of Spain in the Catalonian provinces has brought new evidence bearing on the general subject of the boundary between Pliocene and Pleistocene.

On the Pliocene marine beds rests a continental sequence, which appears to correlate with the well-known lacustrine beds of Astian age found in the Roussillon basin of France. Later events are represented by rather widespread erosion surfaces and a sequence of river terraces. Calcareous caliche representing arid conditions is reported on erosion surfaces and river terraces, all of which are younger than the Astian. The Villafranchian age of the higher terraces is indicated by the presence of *Mammuthus* (*Archidiskodon*) *meridionalis*. The physiographic similarity of the older to the younger terraces suggests similarity of environmental conditions at the time of deposition. The generally admitted periglacial significance of the river terraces in Catalonia suggests that the Villafranchian stage may be considered Pleistocene and of periglacial significance.

GENERAL STATEMENT

SEVERAL observations on the Plio-Pleistocene sequence all along the Catalonia Coast are gathered together here. The author is still working up his data and therefore the results here presented are only provisional.

Acknowledgment is due to the Lucas Mallada Spanish Geological Institute which granted a fellowship in order to make possible this study. Gratitude is also due to Prof. Luis Solé (University of Barcelona) whose guidance and criticism have been of great help. The author is indebted to Prof. Kirk Bryan (Harvard University) for the revision of the manuscript.

THE SEQUENCE IN THE AMPURDÁN

The sandy gravelly materials overlying the marine Pliocene series (Plaisancian-Astian) of Ciurana (Ampurdán) (Fig. 1) have been described in a former paper (Ribera, Villalta and Crusafont, 1945). A molar of *Anancus arvernensis* (Croizet et Jobert)* permitted the attribution of these materials to the Pliocene as defined by Gignoux (1943), Pilgrim (1944) and others. However, the lack of sufficient palaeontological evidence does not permit us to state whether they belong to the Villafranchian stage or not.

Later Bourcart (1947) published his study on the Pliocene and Pleistocene beds of the similar basin of the Roussillon in France, thus extending the work of Depéret (1885), Birot (1937) and others. Bourcart places the so-called lacustrine Pliocene between the Lower Pliocene and the Villafranchian. These lacustrine beds resemble in some aspects the beds in similar stratigraphic position in the Ampurdán. The limestones of the lacustrine formation in the Roussillon seem to be the equivalent of our concretionary sandy marls. Bourcart states that the " Lacustrine Pliocene " rests unconformably above the marine Pliocene. Unfortunately, we cannot make any definite statement concerning the relationships between our continental Pliocene and the underlying marine Pliocene at Ciurana, because of insufficient exposures.

* G. G. Simpson's (1944) modification of H.F. Osborn's (1936–42) nomenclature of the Proboscidea is used here.

Red quartzose gravel of Villafranchian age is described by Bourcart (1947) from certain small areas in the Basin of the Roussillon. The wider distribution and major importance of similar deposits has been recently re-emphasized by Birot (1948). These gravels resemble certain red gravelly soils containing only siliceous pebbles, which are found in a few small areas at the top of hills in the Ampurdán. These gravels have dubious stratigraphic relationships with the apparently older Pliocene beds. Furthermore, doubt exists as to whether they represent the Villafranchian, because of lack of vertebrate fossils. They may represent one or several warm periods of the Pleistocene.

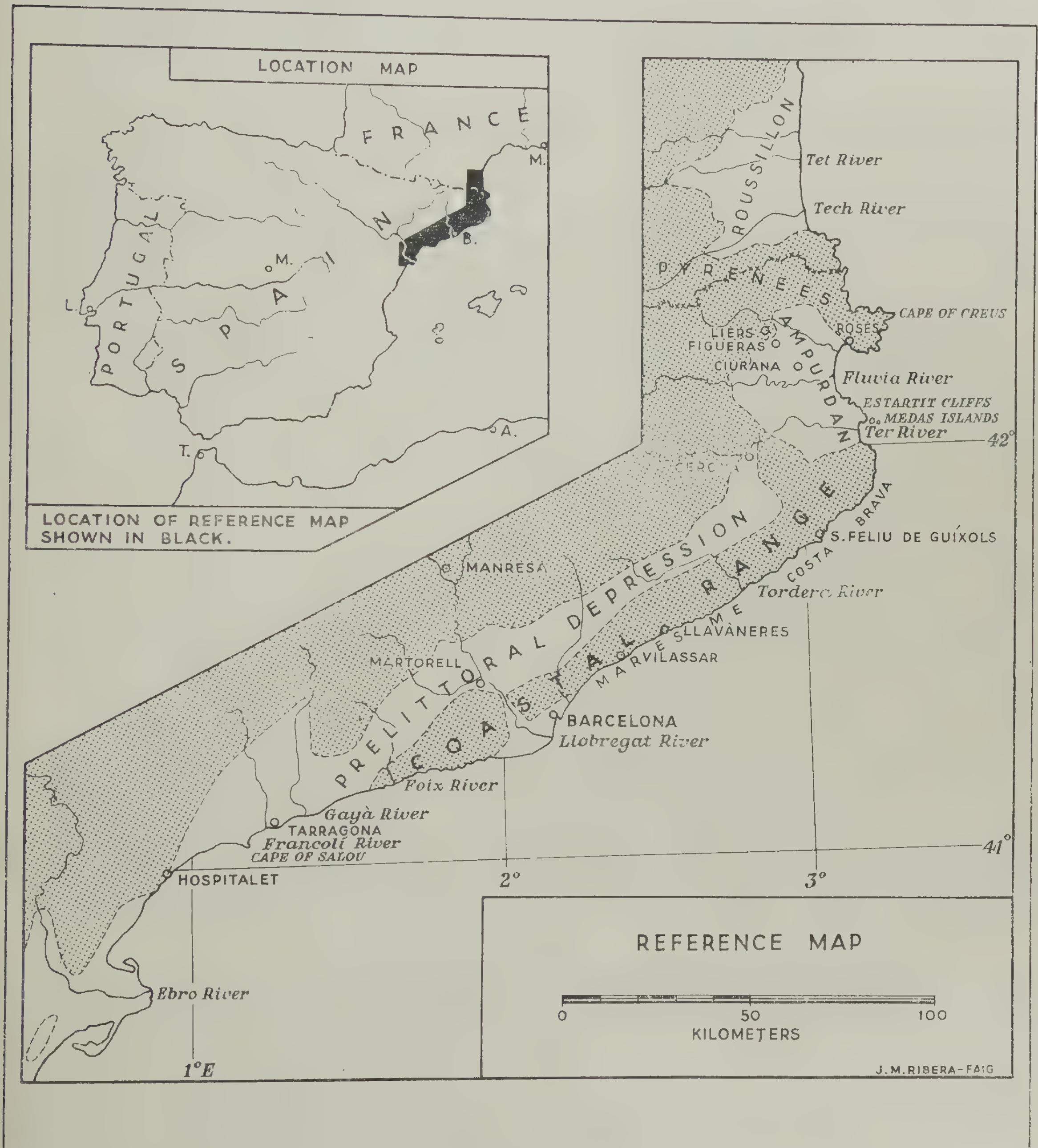

FIG. 1.

Evidence has been found in the Ampurdán which allows the establishment of a sequence of events later than the time of deposition of the continental Pliocene. A widespread erosion surface (Lladó surface) is found all the way around the basin that bevels all beds ranging in age from the Palaeozoic to the Pliocene. The Llers plateau, described by Birot (1937) seem to be a part of the Lladó surface. Other remnants of the same surface were described by Carandell (1943) developed on Cretaceous beds forming the Estartit sea cliffs (Fig. 1). At the north end of this rough coast, in the Gulf of Rosas, Pliocene beds are cut by the Lladó surface. This surface dips very gently eastward, and its eastern remnants cap the Medas Islands at some 70 m. (230 feet) above present sea-level. In the eastern Ampurdán remnants of a limestone layer cap the Lladó surface. This limestone appears to be an ancient layer of caliche* deeply weathered. The present-day valleys are entrenched 50–80 m. (160–260 feet) in this surface.

The Fluviá River has two higher terraces, each capped by caliche and reddish clay and silt overlying gravel (Fig. 2). There are also two lower terraces of gravel and silt, neither red nor calichified. Their heights are about 60 m., 25 m., 10 m., and 4 m. (200, 80, 33, and 13 feet). Solé and Llopis (1939) in the study of the northern termination of the Catalonia Coastal Range, and the report on the geological map of the Gerona sheet (Solé and Marcet, in press.) show similar sequence of terraces in the Ter River and in the Southern Ampurdán, though with somewhat different altitudes and in a worse state of preservation.

THE COASTAL RANGE NORTH OF BARCELONA

On the coast between the Ampurdán and Barcelona there are several features which indicate the presence of a somewhat similar sequence of Pleistocene events. Remnants of the 70–80 m. " Lloret surface " found on granite in the scenic " Costa Brava " are the presumed equivalent of the Lladó surface. Llopis and Ribera report the presence of an older calichified colluvial Pleistocene deposit which is penecontemporaneous with a much dissected terrace in the vicinity of the town of San Feliu de Guíxols. There are also in this place two lower non-calichified terraces associated with younger non-calichified colluvial deposits.

All along the coast between the Tordera River and Barcelona, there are remnants of an erosion surface developed on the granite at 80–100 m. (260–330 feet) and two Pleistocene colluvial deposits (Ribera, 1945). The older colluvial deposit is deeply calichified. Marine layers reported by Solé and Villalta (1939) appear to lie at the base of the younger colluvial deposit. The relation of the marine layers referred to above, to the well-known marine layers at Vilassar reported by Almera is as yet obscure.

THE LOWER COURSE OF THE LLOBREGAT RIVER AND THE BARCELONA PLAIN

The lower part of the Llobregat River has been also studied, and several new facts have been established. The Plaisancian-Astian series fully described by Almera (1895) has been revised. The marine beds described by him do not grade up into thick continental beds as in the Ampurdán but instead, they grade laterally into deltaic and estuarine gravelly deposits not as yet described, at the northern extremity of the narrow Pliocene gulf. In this northern area, near Martorell, the Plaisancian-Astian river gravels described above, are located at an altitude of approximately 160 m. (525 feet) above the present river level.

The terraces of the Llobregat River have been studied by San Miguel and Marcet (1928) and by Ribera and Fontbote (1944). At least six terraces are present south of Manresa. The higher terrace

* The Spanish-American term of caliche is used here for arid soil lime accumulations, following a widespread tendency of North American geologists. This popular name, used in the arid south-west part of the United States to designate this type of soil deposits, was incorporated into the scientific American literature in the earlier nineteen hundreds. However, in view of the world wide occurrence of these deposits in Pleistocene materials of various temperate and subtropical countries, it should be desirable to search for a more specific word. Caliche is not a suitable scientific term, because of the diverse meanings which it has received throughout the American continent.

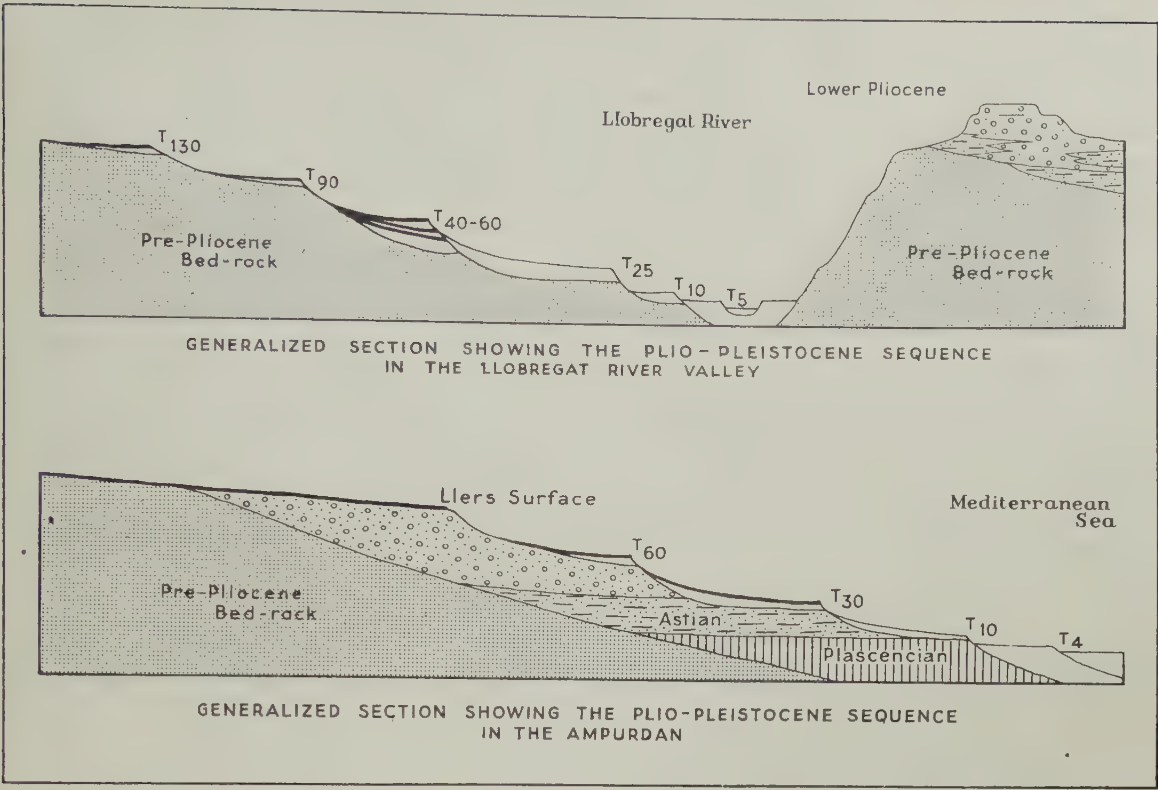

FIG. 2.

is represented by a few hill-top remnants at altitudes about 140 m. (460 feet) near Manresa. In the Prelittoral Depression, however, at about 15–20 km. downstream, the altitude of this terrace is about 130 m. (425 feet) (Figs. 1 and 2). This terrace is probably related to widespread erosion surfaces found all around the Manresa Basin and also in the Prelittoral Depression by the valley of the Llobregat.

The second terrace is also sparingly found and lies at an altitude* of about 90 m. (205 feet). In its gravels a tusk of *Elephas* was found by Solé and Masachs (1940) near Manresa. Villalta (1947) reports that later studies on a molar recently found in the same locality, prove that the elephant is *Mammuthus* (*Archidiskodon*) *meridionalis.* Therefore, the Villafranchian age of the higher terraces appears to be established.

A better preserved terrace is also found in various localities of somewhat variable altitude. This terrace has caliche layers, which in some places are interbedded with thick colluvial deposits. The still higher terraces already described also have caliche layers, although it is difficult to determine precisely whether their calichification is older than or contemporaneous with that of this lower terrace. Colluvial

* The altitude of the terraces is here given with relation to the low water level of the river. However, the figures here reproduced are only provisional and approximate, having in general a maximum possible deviation of 5 metres for the higher terraces and of 1-2 metres for the lower terraces. The figures represent the average height of the top of the terrace as found to-day after being horizontally and vertically dissected, farmed and superficially eroded. The higher terrace remnants and consequently their grade line are likely here to be given altitudes lower than the true grade line, because of their general lack of upper flood deposits. The altitude of the lower terrace remnants and consequently of the grade line may be exaggerated because of the difficulty of lithological separation between the flood deposits and the overlying colluvial materials. Moreover, exact figures would require a larger amount of data, because of the tendency of the grade line of the terraces to decrease in relative altitude towards the sea.

calichified materials reported by Llopis (1942) as forming the Barcelona Plain are apparently to be correlated with this terrace.

Finally, there is a set of three lower terraces, generally in good state of preservation and with no caliche deposits. The higher or 25 m. (80 feet) terrace of this set is the best preserved and developed terrace on the whole river. An intermediate terrace of minor importance is found in many places at about 10 m. (33 feet). The lower terrace, about 4–5 m. high (13–16 feet) is specially well developed in the lower part of the river, but appears also upstream.

THE COAST SOUTH OF BARCELONA

Although with some differences which will be discussed in detail in a later paper, observations carried on along the coast south of Barcelona, show that the Pleistocene sequence is essentially the same as that in the northern section. The small rivers Foix, Gayá and Francolí display terrace systems in agreement with the general sequence. However, the younger strongly calichified terraces and colluvial deposits seem to have been developed more widely as a part of the geomorphic effects of increasing aridity as we move southwards. Consequently, the remnants of older erosional and depositional cycles are more and more sparingly found in southern areas. The marine deposits reported by Bataller (1930) and by Bataller and Vilaseca (1923) south of Tarragona, appear to be younger than the calichified series.

THE SEA-LEVEL FLUCTUATIONS

The Plaisancian-Astian sea-levels seem to have reached an altitude of some 130–140 m. (425–460 feet) above the present sea-level, as inferred from the Pliocene exposures in the Llobregat valley. However, in the Ampurdán basin the maximum height of the Pliocene marine deposits does not exceed 40 m. (130 feet), but this limiting altitude is not evidence of original height because of post-Pliocene subsidence (Ashauer, 1934; Ribera, 1945).

The Pleistocene sea-level movements known elsewhere in the Mediterranean basin, are not recorded on the Catalonian coast. No sequence of marine terraces exists which can be correlated with the reported system of river terraces. The rare marine deposits lie generally below 2 m. (6 feet) above sea-level. The colluvial calichified series is everywhere seen along the seashore to extend below the present sea-level, thus showing a similarity to certain North African deposits described by Bourcart (1936).

Sinking of the coastal belt of Catalonia during Pleistocene times is indicated by structural features resulting from very recent diastrophic processes. These features consist either of continental flexure in the sense defined by Bourcart (1938) or in fault systems parallel to the coast (Llopis, 1945). Pleistocene eustatic phenomena, however, are also responsible for certain features of the shoreline geomorphology and submerged topography of this part of the coast. Raised beaches and wave-cut surfaces reported by Llopis (1945) at the Cape of Creus, seem to be related to eustatism. Eustatic sinking of the sea-level can be supported by the uniform altitude of the remnants of the 70–80 m. (230–260 feet) surface in both areas of subsidence and of uplift. The well-known submerged " Sicilian " deposit off-shore from Cape of Creus, whose special characteristics are explained in terms of a continental flexure by Bourcart (1947), seems to be better explained by the eustatic hypothesis.

GENERAL RESULTS AND POSSIBLE INTERPRETATION

Panzer's (1934) attempt to correlate the Catalonian river terraces according to their relative altitude met some difficulties because of the differences in height which contemporaneous terraces may have in different valleys. If the correlation is based both on relative altitude of the terrace remnants and on supplementary lithological and physiographical criteria, the correlation can be made with more confidence. The correlation presented in the foregoing pages is based mainly on detailed study of the topographic, physiographic and lithologic features of the terraces. This study suggests the correlation of the highest terrace levels of the Llobregat with the Lladó surface found in the Ampurdán. The presence of *Mammuthus* (*Archidiskodon*) *meridionalis* in the 90 m. (270 feet) terrace of the Llobregat

river indicates its Villafranchian age. The red clays containing siliceous pebbles of the Ampurdán may be actually equivalent to similar formations of the Roussillon basin claimed by Bourcart to be of Villafranchian age (1947).

Now, if according to dominant ideas the Villafranchian is considered to be Late Pliocene, the Catalonian Pleistocene is represented merely by a calichified terrace and a set of two or three younger, non-calichified terraces. This interpretation seems not to provide a sufficiently long sequence to fit the expected number of erosional and depositional events of the Pleistocene, controlled all over the world by general shifting of the major climatic zones.

On the other hand, the lithologic and geomorphic similarity between the Villafranchian terraces and the lower ones would indicate similar depositional and erosive conditions for both sets of terraces. Thus the inclusion of the Villafranchian as the Lower Pleistocene would be supported. In this way, an attempt may be made to correlate the deposits of the Catalonian coastal zone with the Plio-Pleistocene chronology. The Lower Pliocene would include the Plaisancian-Astian beds deposited in the bays and wider gulfs of the coast. An Upper Pliocene would be represented by the continental series which in the Ampurdán overlies those deposits. The Lower Pleistocene would include the high terraces of the Llobregat River, of presumed Villafranchian age, and red gravelly clays of the Ampurdán. Widespread erosion surfaces of a partial peneplain type are associated with these deposits. The Great Interglacial would be represented by the river valleys entrenched in these surfaces. The younger calichified terrace and the old and relatively thick colluvial calichified deposits would be correlated with the Riss glaciation and Riss-Würm interglacial stage, and the young non-calichified lower terraces would represent the several substages of the Würmian glaciation. Evidence exists furthermore of a recent transgression of the sea into the river valleys, of possible Flandrian age.

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IL PLIOCENE E IL POSTPLIOCENE DELL 'EMILIA

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Italy

ABSTRACT

The main results of the study of the Pliocene and Pleistocene of Emilia (Northern Italy), based upon several years of research, are given. The Pliocene has been divided into three stratigraphical members instead of the usual two. In the Pleistocene four members are recognized: Calabrian, Emilian, Sicilian, and Milazzian. These are characterized by faunal changes brought on by climatic variations. The Emilian is a new marine unit with mild-climate faunas. Correlations with continental Quaternary facies are also attempted.

ERA nostra intenzione pubblicare, prima dello schema che qui presentiamo, dei lavori stratigrafici e paleontologici di dettaglio sulle serie plioceniche e postplioceniche dell'Emilia; tuttavia crediamo non sia fin d'ora inopportuna una esposizione sintetica dei principali risultati raggiunti dopo oltre un decennio di ricerche di campagna e di laboratorio. Premettiamo che la presente sintesi, pur essendo in buona parte definitiva, presenta ancora delle lacune, che ci proponiamo di colmare in un prossimo futuro; come pure ci ripromettiamo di rendere noti in altra sede i documenti dettagliati, da cui provengono queste conclusioni.

Le zone che sono state oggetto delle nostre ricerche sono: il margine settentrionale dell'Appennino emiliano (soprattutto bolognese e romagnolo, essendoci limitati per il rimanente allo studio di alcune serie caratteristiche) e numerosi pozzi, perforati nella pianura del Polesine, Ferrarese e Ravennate.

I. PLIOCENE

Benchè il Pliocene emiliano sia notoriamente preso come tipo di questo periodo e in particolare per il bacino mediterraneo, le troppo frequenti confusioni e inesattezze, che si sono commesse anche in lavori molto recenti, con errate assimilazioni di terreni più antichi o più recenti, rendono necessario un rapido cenno di revisione.

La serie pliocenica si inizia con una generale trasgressione, che nel subappennino è sempre marcata da una netta discordanza angolare, con la diretta sovrapposizione di argille su terreni più antichi; assai raramente si presenta un conglomerato basale vero e proprio, che in qualche caso può essere sostituito da un tenuissimo spessore di sabbie o argille sabbiose con fossili miocenici rimaneggiati. Il Pliocene è superiormente troncato ora dalla trasgressione calabriana, ora da quella milazziana, ora addirittura dai terrazzi alluvionali recenti. Lo spessore complessivo della serie è molto variabile e raggiunge talora valori notevolissimi (650 m. a Castellarquato, 550 nel Pliocene intrappenninico bolognese, oltre 1000 m. nell'Imolese).

Normalmente il problema della stratigrafia pliocenica non viene neppure posto dagli AA., i quali considerano come esatta e di generale applicazione la suddivisione in due termini: argille azzurre inferiori (Piacenziano), sabbie gialle o molasse o conglomerati superiori (Astiano). In realtà la stratigrafia del Pliocene è assai più complessa, per la varietà delle facies e i mutamenti avvenuti nelle associazioni faunistiche e negli ambienti di sedimentazione. Abbiamo perciò trovata più opportuna e generale una suddivisione in tre piani* basata sui caratteri paleontologici e non in funzione delle

* Una suddivisione analoga, basata sulle faune malacologiche soltanto, fu adottata oltre 80 anni fa da Cocconi (1813); però essa non fu più seguita (almeno per quello che ci è noto), forse per la difficoltà di rinvenire faune a molluschi sufficientemente ricche.

facies, per le quali sono stati spesso proposti termini infelici privi di un preciso significato cronologico (Fossaniano, Sansino, Piacenziano pseudoastiano, ecc.).*

1. *Pliocene inferiore*.—(= Tabiano, Doderlein e Cocconi†). E'rappresentato costantemente da argille, salvo che nel bacino intrappenninico bolognese, dove queste sono rapidamente sostituite verso l'alto da argille sabbiose, molasse e infine da conglomerati. Fossili caratteristici sono: *Murex spinicosta, Pirula ficoides, Fusus rarocingulatus, Astraea fimbriata, Robulus ariminiensis, R. clypeiformis, Lingulina costata, Marginulina spinicosta, Cribrorobulina serpens* sp., *Uvigerina semiornata, Ellipsoidina ellipsoides*, ecc.‡, che nella quasi totalità sono diffusi già nel Miocene e tutti mancano nei livelli successivi. Sono presenti, anche se scarse, forme nuove che si continuano nei piani più alti, mentre la parte preponderante della fauna è costituita da specie comuni al Miocene e al Pliocene. In definitiva si può dire che il Pliocene inferiore è separabile dal Miocene solo per la presenza della trasgressione basale, perchè da un punto di vista strettamente paleontologico sarebbe più esatto includerlo nel Miocene. Questo fatto non è limitato all'Appennino emiliano, ma si ritrova anche nel resto d'Italia e in Albania. Classico è il caso dei " trubi " della Sicilia che si trovano in una situazione analoga; infatti essi sono stati considerati miocenici dagli AA., che hanno dato maggior peso ai caratteri paleontologici, e pliocenici da coloro che hanno considerato prevalentemente la giacitura della roccia.

2. *Pliocene medio*.—Con l'inizio del Pliocene medio assistiamo generalmente a una diminuzione di profondità del fondo marino, che talora può avere portato a una breve emersione (Castrocaro); tale diminuzione di profondità in certi casi si continua graduale per tutto il resto del Pliocene (Castellarquato), mentre in altri è stata bruscamente interrotta da un nuovo aumento di profondità (Forlivese e Bolognese), che talora ha raggiunto valori cospicui. E'perciò notevole la varietà delle facies dei terreni: dalle argille, alle sabbie e talora anche ai calcari organogeni (Castrocaro). Le faune hanno di conseguenza una notevole varietà; carattere comune è la scomparsa delle forme eoplioceniche sopra elencate e la comparsa di nuove specie che si continueranno anche nei livelli successivi. Fra queste ultime abbiamo: *Murex erinaceus, M. absonus, Dentalium rectum, Hinnites crispus, Soldania mytiloides, Angulogerina angulosa, A. fornasinii, Sigmoilina sigmoidea, Planulina wuellerstorfi* var., *Robulus felsineus* ecc., e la ricomparsa del genere *Amphistegina*. Altre specie sono in comune con il Pliocene inferiore ma mancano nel superiore: *Achamptochetus mitraeformis, Philbertia textilis, Drillia obtusangula, Mitra bellardiana, Typhis fistulosus, Megasurcula cataphracta, Turris monilis, Verticordia argentea, Uvigerina bononiensis*, ecc.

3. *Pliocene superiore*.—Nel Piacentino e nel Parmense si continua regolare l'emersione iniziatasi col Pliocene medio fino a dar luogo a caratteristici depositi deltizi (Castellarquato), nel Forlivese invece persiste l'ambiente di mare profondo iniziatosi nel Pliocene medio. In altre zone (dintorni di Bologna e alcuni punti del substrato padano) il Pliocene superiore può mancare completamente per il precoce inizio della regressione soprapliocenica; talora poi le azioni erosive precalabriane possono aver determinato l'abrasione non solo della porzione di Pliocene superiore eventualmente depositatasi, ma anche del Pliocene medio o addirittura dell'inferiore. Quindi il Pliocene superiore spesso manca e, quando è presente, si manifesta con una notevole varietà di facies (tutti i tipi di sedimenti clastici e talora calcari organogeni). Occorre infine osservare che il limite Pliocene medio-superiore è assai meno ben definibile di quello Pliocene inferiore-medio. Compaiono nel piano in esame alcune forme che si continuano anche nel Quaternario e cioè: *Astarte sulcata pseudofusca, Teretia teres, Nucula*

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* Già il De Stefani (1891) aveva messo in evidenza lo scarsissimo valore cronologico delle facies plioceniche. Malgrado il generale consenso suscitato da questa affermazione, troppo spesso si continua ancor oggi a suddividere il Pliocene in piani definiti quasi solo dalla natura litologica dei terreni.

† Secondo il significato dato originariamente de questi due AA. Gli AA. successivi fecero purtroppo di questo termine, come pure degli altri più noti (Piacenziano e Astiano), un uso spesso improprio. (De Stefani, 1891).

‡ Questo breve elenco e gli altri che daremo in seguito sono puramente indicativi. E'infatti possibile fare della stratigrafia di dettaglio (particolarmente del Pliocene e Quaternario) solo con lo studio delle associazioni faunistiche e con le frequenze relative delle singole specie. Insolubile rimarrebbe invece il problema se ci si limitasse solo alla ricerca dei cosidetti fossili guida.

decipiens, *N. tenuis*, *Tapes aureus*, *T. rhomboides*, *Clathurella linearis*, *Mangilia coerulans*, *Spiroplectammina wrigthii*, *Astrononion tumidum*, *A. stelligerum*, ecc. Si assiste inoltre alla fine del Pliocene superiore alla scomparsa di un gran numero di specie (talora anche di generi e di famiglie), per il cui elenco rimandiamo a Gignoux (1913).

Località caratteristiche, in gran parte già ben studiate, si possono considerare: per il Pliocene inferiore Tabiano e Maiatico (Parma); per il Pliocene medio con facies argillosa sublittorale S. Maria Maddalena (Castellarquato), con facies calcareo-organogena Castrocaro (Forlì), con facies argillosa profonda Ponticello di Savena (Bologna); per il Pliocene superiore Riorzo (Castellarquato) e Capocolle (Forlì), entrambe di facies littorale.

Come si vede manca al Pliocene una vera e propria unità faunistica, poichè la porzione meglio individuata rispetto al Miocene da un lato e al Quaternario dall'altro è solo il complesso costituito dal Pliocene medio e superiore, i quali appunto per questo sono meno nettamente delimitabili fra loro. Il Pliocene inferiore invece ha, da un punto di vista paleontologico, maggiori relazioni col Miocene che non con il Pliocene medio. Si può dire perciò che le faune mioceniche, affini alle attuali indopacifiche, si estinguono con il Pliocene inferiore e che col Pliocene medio sono sostituite gradualmente da altre, che assumeranno la loro fisonomia definitiva durante il Quaternario, ad affinità atlantiche.

Il Pliocene non è neppure ben caratterizzato stratigraficamente, non costituendo ovunque un unico ciclo sedimentario. Infatti in Romagna e in parte anche nel Bolognese si sono avute oscillazioni notevoli del fondo del mare pliocenico e talore vere e proprie emersioni temporanee. Infine, se si può considerare rapida e ovunque coeva la trasgressione della base del Pliocene, la regressione sopracliocenica è stata assai lenta e in alcune zone è cominciata fin dal Pliocene medio.

Finora si è considerato il clima del Pliocene uniformemente caldo e umido. Però certe anomalie riscontrate fra associazioni faunistiche da un lato e facies, condizioni paleogeografiche e tettoniche dall'altro fanno supporre che durante il periodo siano avvenute delle variazioni climatiche, anche se di modesta entità.

II. CALABRIANO E SICILIANO

Col termine di Calabriano gli AA. (Ruggieri, 1944; Selli, 1946; Alliata, 1946) hanno indicato nel Subappennino emiliano e nel substrato della Pianura Padana un complesso marino, prevalentemente argilloso, spesso di grande potenza e caratterizzato da faune con frequenti ospiti atlantici sconosciuti nel Mediterraneo durante il Pliocene. Inoltre nella Pianura Padana questa formazione è sempre trasgressiva su altre più antiche, mentre nell'Appennino è solo supponibile come tale, mancando finora dati decisivi al riguardo.*

La potenza di questo complesso è assai variabile; si passa infatti da poche decine di metri sulla sommità dei rilievi terziari sepolti sotto la coltre quaternaria della pianura, a parecchie centinaia di metri (600 m. e più presso il littorale adriatico del Polesine, 800 m. nei dintorni di Imola).

Il limite superiore della formazione è nettissimamente segnato nel Subappennino fra Imola e Forlì dalla sovrapposizione trasgressiva e discordante delle sabbie gialle attribuite da Ruggieri (1944) al Siciliano; a Castellarquato invece è troncato dai terrazzi alluvionali recenti. Nella pianura padana non è altrettanto ben riconoscibile un limite superiore, in quanto vi è stata, almeno apparentemente, continuità di sedimentazione coi depositi continentali sovrastanti† ai quali si è passati mediante un ripetuto alternarsi di condizioni marine, deltizie, lagunari e palustri (1946).‡

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* Come è noto Gignoux (1913) sostenne esservi continuità di sedimentazione fra Calabriano e Pliocene. La trasgressione calabriana fu però già dimostrata per la Sicilia (Trevisan, 1938), Catanzarese (Ruggieri, 1941) e altri punti della Calabria (Seguenza, 1880), dintorni di Roma (Cerulli, 1907) e nella Pianura padana (Selli, 1946; Alliata, 1946).

† Solo Alliata (1947) ha accennato alla giacitura discordante sopra il Calabriano di un complesso marino, attribuito al Siciliano.

‡ Questo cambiamento ambientale non è stato ovunque contemporaneo, perchè in funzione delle condizioni paleogeografiche regionali, a loro volta per buona parte dipendenti dall'andamento delle strutture precalabriane.

Nella Pianura padana il complesso si può suddividere, dal basso all'alto nelle seguenti zone stratigrafiche.*

1. *Zona A.*—Argille marine di limitata profondità poggianti in discordanza su terreni terziari. In qualche punto vi è un conglomerato basale con fossili pliocenici rimaneggiati e una netta discordanza angolare rispetto ai terreni sottostanti; spesso però, per la diretta sovrapposizione di queste argille a quelle plioceniche, non è possibile stabilire a priori l'esistenza della trasgressione basale; in tal caso (ad es. Pontelagoscuro) possono servire di guida solo le faune, che però già a prima vista sono distinguibili da quelle sottostanti plioceniche per il magnifico stato di conservazione. Fra i macrofossili è caratteristica la *Cyprina islandica*. Le microfaune sono ricche di specie (40–80 (†)) specialmente alla base e caratterizzate dalla persistenza di alcune forme plioceniche, cui si aggiungono varie specie oggidì solo o prevalentemente atlantiche (*Anomalina balthica, Nonion germanicum, N. depressulum, Elphidium advenum, Discorbis mamilla, D. opercularis, D. praegeri, Pulvinulina frigida, Bolivina spathulata*, ecc.) e altre che nel Pliocene vivevano a maggior profondità (*Biloculina depressa, Cassidulina crassa, Ehrenbergina bradyi, Angulogerina angulosa, Bulimina* spp., *Nonionella turgida, Sigmoilina sigmoidea*, ecc.).

2. *Zona B.*—Argille marine ancora di piccola profondità e talore un pò sabbiose. Microfauna estremamente povera (per lo più con solo 15–25 specie) costituita da forme banali, di facile adattamento e spesso in gran numero di individui; rare o addirittura mancanti le specie caratteristiche della zona A. Da notare in certi casi la presenza, presso la base della zona, di un livello a ciottoli sparsi e Foraminiferi rimaneggiati (perfino paleogenici).

3. *Zona B*1.—Argille sabbiose di scarsa profondità. Microfauna generalmente un po' più ricca (fino a 30–35 specie) della precedente priva di elementi nordatlantici e perciò simile a quella attuale nordadriatica (p. es. Porto Corsini e Lido di Venezia), salvo la minor ricchezza di forme.

4. *Zona C.*—Argille sabbiose e sabbie argillose. Microfauna analoga alla precedente per numero di specie, ma caratterizzata dalla ricomparsa di molte forme tipiche della zona A (*Anomalina balthica, Cassidulina crassa, Nonion germanicum*, ecc.).

5. *Zona D.*—Sabbie argillose e argille sabbiose talora con abbondanti Nullipore. Microfauna analoga a quella della zona B1, ma di mare più tepido paragonabile allo Jonio attuale.

Sopra cominciano (spesso anche verso l'alto della zona D) le prime alternanze deltizie e palustri, cui si intercalano nuovi livelli marini; infine l'ambiente continentale si instaura definitivamente per continuare fino all'attualità.

La tipica successione descritta schematicamente, presenta una marcata costanza nella pianura del Polesine e in altre zone della pianura padana. Sulla sommità però dei rilievi terziari (dove può in certi casi addirittura mancare) o nelle immediate vicinanze, la serie subisce una notevole riduzione, modificazioni litologiche e talora intercalazioni di depositi deltizi o continentali-palustri per cui in certi casi i parallelismi con la serie nettamente marina suaccennata possono riuscire difficoltosi. Naturalmente è inutile, dato lo spazio che richiederebbe, intrattenersi qui sia su queste variazioni laterali, sia sui caratteri di dettaglio dei complessi sovrastanti alla zona D. Il rapporto di spessore fra le varie zone stratigrafiche ha una certa variabilità; tutto il complesso rappresenta inoltre normalmente la parte preponderante (da 1/2 a 2/3 e talora anche più) di tutta la serie postpliocenica della pianura.

Il complesso presenta una successione perfettamente analoga lungo il margine dell'Appennino; è però solo in Romagna, fra Castel S. Pietro e Santarcangelo (in modo particolare fra Imola e Forlì) che esso è assai svilippato e pressochè completo. Infatti a Castellarquato affiora solo la zona basale,

* Questi dati provengono da ricerche inedite su numerosi pozzi; data la provenienza dei campioni, sono state solo le microfaune a rendere possibile la stratigrafia di dettaglio.

(†) Questi valori si riferiscono non al numero complessivo delle specie presenti nella zona A, ma a quello medio riscontrato in spessori molto esigui (solo pochissimi decimetri). Ciò vale anche per i numeri citati per le altre zone stratigrafiche.

fra Castellarquato e Vignola non esistono finora ritrovamenti incontrovertibili della presenza (per quanto in qualche punto sia probabile) delle zone più profonde (zone A-C della pianura), che fra Vignola e Castel S. Pietro mancano certamente. Nei dintorni di Imola la serie si presenta quasi completamente argillosa e direttamente poggiante sulle argille plioceniche; solo alla base e all'apice si presentano due zone stratigrafiche con faune a *Cyprina islandica*, fra loro molto simili e corrispondenti alle zone A e C della pianura; la parte intermedia invece della serie contiene faune banali e per lo più assai povere senza i caratteri delle altre due ed è perciò sincronizzabile con le zona B della pianura.

Sopra questa serie in Romagna, o direttamente su terreni più antichi nel Bolognese, poggiano trasgressive con una marcata discordanza angolare le sabbie gialle, contenenti una malacofauna abbondante (Ruggieri, 1944) e resti di *Elephas*, *Hippopotamus*, *Bos*, ecc.* Questa formazione littoranea o deltizia presenta caratteri perfettamente analoghi a quelli della zona D della pianura.

Occorre infine ricordare che i limiti fra le zone citate sono normalmente solo paleontologici, mancando, salvo l'eccezione testè nominata, variazioni litologiche o fenomeni trasgressivi, che potrebbero meglio marcare le suddivisioni. Data anche la persistenza di alcune specie malgrado le variazioni ambientali denunciate dal resto della fauna, i passaggi fra le zone stratigrafiche sono per lo più graduali. Ciò si verifica in modo particolare per le zone B e B1, la cui delimitazione precisa è spesso assai difficile.

Già dai dati sommariamente esposti risulta un dato di fondamentale importanza: nella parte orientale della Pianura Padana e al margine dell'Appennino emiliano-romagnolo, sopra il Pliocene poggia trasgressivo un potente complesso nel quale si possono individuare quattro zone stratigrafiche regolarmente alternate; le zone A e C caratterizzate da faune con ospiti nord-atlantici, le zone B–B1 e D da faune simili (salvo la grande povertà di specie) alle attuali dell'Adriatico e dello Jonio. Le tre zone più profonde sono sempre in continuità stratigrafica fra di loro, mentre la quarta, in continuità con la sottostante nella pianura, è trasgressiva al margine dell'Appennino.

Si è molto spesso insistito dagli AA. sul carattere "freddo" delle faune calabriane e siciliane; è questa un'espressione poco precisa o per meglio dire incompleta, che conviene chiarire. Durante il Quaternario si è avuta a varie riprese la comparsa nel Mediterraneo di forme che hanno un habitat attuale prevalentemente atlantico. Durante il Calabriano inferiore e Siciliano inf. (preciseremo meglio fra poco questi termini) apparvero molte specie che oggi vivono di preferenza o solo nell'Atlantico settentrionale, ma anche varie altre, oggi non più note nel nostro mare e viventi nell'Atlantico centrale (Mediterraneo americano). Nel Tirreniano invece, come mostrano nettamente le microfaune, e in parte anche le macrofaune, si è avuta la prevalente comparsa nel Mediterraneo di specie ad habitat centroatlantico, insieme ad altre, per quanto non numerose, oggi viventi nell'Atlantico del N. Cioè a noi sembre che il carattere fondamentale delle faune marine quaternarie del Mediterraneo sia essenzialmente oceanico-atlantico, con modificazioni in senso freddo (meglio temperato-freddo) o temperato a seconda delle condizioni climatiche; tali modificazioni sono poi state assai meno accentuate di quel che farebbero credere a prima vista le espressioni comunemente usate di "faune a *Cyprina islandica*" o "a *Strombus bubonius*." L'esame dei caratteri paleobiologici delle associazioni faunistiche sarebbe quanto mai interessante, ma richiederebbe spazio, anche per un rapido cenno. Si può però osservare che anche le variazioni di salsedine, il diverso regime delle correnti, ecc. hanno indotto nelle faune marine modificazioni notevoli. Si vedano ad esempio le differenze esistenti fra le faune del complesso quaternario padano con quelle coeve della Calabria.

Si pone ora il problema della correlazione del complesso stratigrafico descritto con il classico Quaternario antico dell'Italia meridionale. A nostro modo di vedere non è possibile attribuire tutta la serie in questione al Calabriano, come si è quasi generalmente fatto finora; troppo notevole è infatti

* La fauna mammalogica delle sabbie gialle di Imola attende ancora lo studio di uno specialista. Gli AA. hanno talora citato in essa delle forme plioceniche (Gignoux, 1914), che sono completamente in contrasto con tutt a la fauna marina di queste sabbie.

nella pianura il suo spessore rispetto ai sedimenti successivi* e troppo marcate e d'altronde regolari le variazioni e il caratteristico ripetersi di associazioni faunistiche. Tuttociò induce a credere che una parte notevolmente lunga dei tempi quaternari sia trascorsa durante la deposizione di questo complesso e che notevoli e ripetuti mutamenti climatici si siano contemporaneamente verificati. Siamo perciò indotti ad attribuire al Calabriano l.s. le zone stratigrafiche più basse (zone A, B, B1) e al Siciliano l.s. quelle più alte (zone C, D) e a fare un'analoga datazione dei corrispondenti livelli dell'Appennino. Una tale sincronizzazione è perfettamente in armonia con le ricerche più recenti sul Quaternario antico e permette inoltre di precisare le ripercussioni determinate sugli ambienti marini dalle più antiche glaciazioni.

Era già stato messo in evidenza l'esistenza di un Siciliano I a carattere freddo (continuiamo per brevità ad usare questa espressione, però con le riserve di cui sopra) e di un Siciliano II (= Milazziano†) a carattere temperato; era però finora solo noto un Calabriano a costante carattere freddo. Le nostre ricerche hanno dimostrato l'esistenza anche di un Calabriano II di tipo temperato per il quale proponiamo il termine di *Emiliano*. Questo piano è caratterizzato da faune di tipo temperato, che, anche se selezionate dal precedente raffreddamento, conservano somiglianze assai più spiccate con le attuali mediterranee, di quelle dei piani adiacenti (Calabriano I e Siciliano I).‡ L'Emiliano corrisponderebbe alla lacuna esistente nell'Italia meridionale e nella Sicilia fra il ciclo sedimentario calabriano e quello siciliano. Il suo riconoscimento, come quello del Milazziano, non sarà possibile a priori, ma solo in quei casi, come nella pianura padana, dove è possibile stabilire il suo contatto normale con il Calabriano I o il Siciliano I, che sono assai meglio riconoscibili mediante le loro faune.§

Da quanto si è fin qui detto è evidente che pure nel Quaternario inferiore si sono risentite nelle faune marine delle variazioni climatiche perfettamente analoghe a quelle del Quaternario superiore, anche se di entità diversa. Viene così a cadere la supposizione di una persistenza delle faune a *Cyprina* per tutto il Quaternario inferiore interrotta solo dalla comparsa delle faune a *Strombus* (Blanc, 1942). Inoltre la comparsa di forme oggi atlantiche non solo nel Calabriano I ma anche nell'Emiliano e soprattutto nel Siciliano I e in parte anche nel Milazziano dimostra che le comunicazioni marine fra Mediterraneo e Atlantico si sono mantenute per tutto il Quaternario inferiore e che numerosi, determinati essenzialmente dalle condizioni climatiche, sono stati gli scambi faunistici.

Come è noto, è assai arduo e privo per ora di una base sicura il tentativo di mettere in relazione il Quaternario continentale con quello marino. Ad ogni modo le variazioni delle associazioni faunistiche e gli altri fatti sono così caratteristici, che saremmo indotti a tentare le correlazioni riportate dalla

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* Attribuendo tutto il complesso al Calabriano e parallelizzandolo, come comunemente si fa, col Günz e l'interglaciale G–M, si potrebbero vedere nelle due zone A e C ad ospiti nord-atlantici i corrispondenti del Günz I e del Günz II. A parte il fatto che non crediamo si possa, almeno per ora, con le sole faune marine arrivare a cosi sottili suddivisioni, si cadrebbe nella seguente contraddizione. Secondo il diagramma del Milankovitch si sarebbe deposto in 120000 anni al più uno spessore di sedimenti in molti casi più che doppio, di quello formatosi nei 480000 anni successivi. E' ben vero che verso l'alto del Quaternario padano sono frequenti le intercalazioni denuncianti un ambiente terrestre, ma a parte il fatto che si tratta di depositi ancora a notevole velocità di sedimentazione (deltizi e palustri) si deve tener presente che rapporti analoghi di spessore si osservano anche nelle serie stratigrafiche in corrispondenza dell'attuale delta del Po dove il carattere marino dei sedimenti persiste fino quasi all'attuale livello di campagna.

† Tale termine è caduto troppo spesso in disuso per il solo fatto che non può essere definito da forme caratteristiche. A noi non pare che sia questo un motivo sufficiente, in quanto è perfettamente logico che si siano ripetute anche nel Quaternario faune fondamentalmente simili alle attuali, e quindi " banali," allorchè le condizioni climatiche e ambientali erano assai simili alle attuali.

‡ Abbiamo spesso parlato di faune marine quaternarie simili alle attuali corrispondenti mediterranee. Generalmente però tale somiglianza si manifesta con l'assenza di elementi nordatlantici (salvo rare e limitate persistenze locali) ma non con uguale ricchezza di specie; le faune temperate come del resto anche quelle " fredde " del Quaternario antico padano sono sempre assai povere di specie.

§ Gli AA. hanno già dimostrato la quasi identità faunistica fra Calabriano I e Siciliano I; ciò si ripete anche nella regione in istudio. Una grande somiglianza intercorre pure fra le faune dell'Emiliano e quelle del Milazziano, per quanto le seconde dimostrino una maggiore mitezza di clima.

tabella allegata. E' forse superfluo avvertire che diamo a quest'ultima, sotto questo riguardo, un valore ipotetico e del tutto provvisorio. Non si può tuttavia sottotacere la corrispondenza che si avrebbe fra gli spessori delle zone stratigrafiche osservate nella nostra regione (dove la grande analogia e persistenza delle facies, e quindi l'analoga velocità di sedimentazione sono evidenti) e la lunghezza teorica dei periodi glaciali e interglaciali desunta dal diagramma del Milankovitch.* Si è già detto come il complesso studiato corrisponda nella pianura Padana orientale a 1/2 e 2/3 di tutta la serie quaternaria locale; un analogo rapporto di tempo intercederebbe secondo Milankovitch fra inizio del Quaternario—fine M–R e inizio del Riss—attuale. Inoltre il maggior spessore dei complessi a faune temperate rispetto a quelli contermini, con elementi nordatlantici, comproverebbe la maggior lunghezza dei periodi interglaciali rispetto a quelli glaciali.

La quasi costante continuità di sedimentazione verificatasi nell'Emilia durante il Quaternario antico, anche presso il margine appenninico (cioè presso le antiche coste) oltre ad essere quanto mai propizia per lo studio di questo periodo geologico permette anche di dire una parola su problemi molto dibattuti quale è quello dell'eustatismo glaciale. A tal proposito è assai interessante ripetere

SCHEMA DELLE SUDDIVISIONI DEL PLIO-PLEISTOCENE DELL'EMILIA

	Facies marine normali	*Caratteri faunistici*	*Caratteri litologici*	*Facies continentali*
Quaternario inf.	Milazziano o Siciliano II	Faune generalmente povere con qualche ospite medio-atlantico. Clima simile a quello attuale del Mare Jonio.	Sabbie gialle trasgressive al margine dell'Appennino. Sabbie argillose e argille sabbiose con ciottoli alla base nella Pianura.	Interglaciale M – R
	Siciliano I	Faune povere con ospiti nord-atlantici. Clima temperato-freddo.	Argille nell'Appennino. Argille sabbiose e sabbie argillose nella Pianura.	Mindel
	Emiliano o Calabriano II	Faune povere con rari ospiti nord-atlantici solo presso la base. Clima simile a quello attuale dell' Adriatico settentrionale.	Argille nell'Appennino. Argille e argille sabbiose con ciottoli alla base nella Pianura.	Interglaciale G – M
	Calabriano I	Faune spesso abbastanza ricche con ospiti nordatlantici, che talora mancano in un leggero spessore alla base. Clima temperato freddo.	Argille nell'Appennino romagnolo; sabbie a Castellarquato. Argille nella Pianura, con un frequente conglomerato basale, sempre trasgressive.	Günz (?)
Pliocene	Pliocene superiore	Faune ricche con le ultime sopravvivenze mioceniche e alcune forme che si svilupperanno meglio nel Quaternario.	Argille più o meno sabbiose o sabbie gialle e conglomerati o calcari organogeni.	
	Pliocene medio	Faune ricche e varie con l'associazione di specie eoplioceniche ad altre soprapliocemiche o quaternarie.	Argille o argille sabbiose o sabbie o calcari organogeni	
	Pliocene inferiore	Faune molto ricche e con molte specie comuni col Miocene sup. o medio.	Quasi costantemente argille.	

* Esula completamente dalla nostra competenza un giudizio su questa interessante ricostruzione.

che nella pianura Padana mancano tracce di emersioni vere e proprie in corrispondenza dei periodi di raffreddamento e di estese trasgressioni connesse con gli interglaciali. Ciò si può spiegare solo in due modi: o le oscillazioni eustatiche sono state completamente bilanciate dalle oscillazioni regionali del substrato, o le oscillazioni eustatiche, ineccepibili da un punto di vista teorico, sono state di valore inferiore a quello talora supposto.* Crediamo, sia pure con qualche riserva, che la seconda interpretazione sia la più aderente alla realtà; perchè, anche tenendo conto della cospicua subsidenza dei bacini padani,† che ha permesso l'accumulo dei potenti sedimenti quaternari su di un fondo marino scarsamente profondo (certamente mai superiore ai 100 m.), non sono osservabili nè cospicue variazioni di profondità, nè emersioni, quali richiederebbero certe valutazioni recenti dell'eustatismo glaciale. Però moderate variazioni del livello marino devono essere avvenute; ciò è dimostrato dalla frequente presenza nella pianura di un livello a ciottoletti sparsi alla base dell'Emiliano e del Milazziano (talora di un vero conglomerato) e la costante giacitura trasgressiva del Milazziano (sabbie gialle) al margine dell'Appennino o dei rilievi più accentuati mediopadani. Cioè le oscillazioni del livello marino possono aver determinato nel Quaternario antico padano solo trasgressioni in prossimità della linea di costa, o leggere variazioni di profondità, ma non hanno certamente determinato il completo ritiro del mare dai bacini padani, come è stato supposto per il Würm.

Come abbiamo detto, gli AA. considerano generalmente il Calabriano in continuità stratigrafica con il Pliocene; si è accennato anche che le ricerche recenti hanno in gran parte demolito questa supposizione. Secondo noi la trasgressione della base del Calabriano è un fatto molto diffuso, se non quasi generale, nella penisola italiana e nella Sicilia. Essa non può avere che un'origine tettonica ed è perfettamente analoga, salvo l'entità, alla grande trasgressione della base del Miocene medio. Essa dimostra cioè l'esistenza di una intensa fase orogenetica postuma del corrugamento alpino. Inoltre la sua concomitanza generale con la prima glaciazione è solo casuale e indipendente da quest'ultima; perchè altrimenti sarebbe in contrasto troppo evidente con l'eustatismo glaciale. In certi casi poi la trasgressione calabriana è lievissimamente anteriore alla prima glaciazione; infatti spesso, immediatamente al di sopra della trasgressione, vi sono associazioni faunistiche prive di ospiti nordatlantici, che compaiono solo un po' più in alto nella serie. Un'altra fase diastrofica analoga è avvenuta dopo il Milazziano al margine dell'Appennino settentrionale, dove le sabbie gialle milazziane sono talora state portate ad oltre 300 m. di quota.

III. CONCLUSIONI E SOMMARIO

Da quanto esposto si può dire che in tutta la serie stratigrafica post-miocenica dell'Emilia esiste un solo limite di grande portata geologica: il limite Pliocene-Calabriano. Esso segna infatti nelle faune la fine delle ultime sopravvivenze ancora mioceniche e l'inizio di faune marine pressochè uguali alle attuali mediterraneo-atlantiche; inoltre è nettamente marcato dall'avvento di un clima a carattere oceanico " freddo " e da una fase diastrofica, che ha determinato la trasgressione calabriana. E' questo l'unico limite che nelle serie marine permette di separere con sicurezza il Pliocene dal Qua ternario.

I risultati di oltre un decennio di ricerche hanno permesso agli AA. di individuare nel Pliocene emiliano tre piani ben caratterizzati dal punto di vista faunistico e, in parte, anche dalle variazioni di facies. Vengono riconosciute nel Quaternario antico quattro zone stratigrafiche ben definite mediante le microfaune, le quali sono l'espressione di profonde variazioni climatiche. La zona più profonda con clima temperato-freddo viene sincronizzata con il Calabriano, per la seconda a clima temperato vien proposto il nuovo termine di *Emiliano*, la terza, a clima temperato-freddo, vien parallelizzata con il Siciliano e infine la quarta, a clima temperato-caldo e marcata da una trasgressione al margine dell' Appennino, con il Milazziano. Sono infine tentate le correlazioni con il Quaternario continentale e

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* Per i valori calcolati anteriormente al 1942 rimandiamo alla bella sintesi di Blanc (1942).

† Le ricerche recenti hanno dimostrato una notevole varietà tettonica nel substrato terziario della pianura Padana; almeno due grandi bacini sono individuabili, l'avanfossa alpina e l'avanfossa appenninica, separate dalla serie dei rilievi mediopadani.

vien dimostrato che le oscillazioni del livello marino, dovute all'eustatismo glaciale, hanno avuto nell'Emilia, durante il Quaternario inferiore, un valore assai minore di quello talora supposto per il Quaternario più recente.

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THE PLIOCENE-PLEISTOCENE BOUNDARY IN LOUISIANA

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ABSTRACT

No outcrop of Pliocene occurs in Louisiana. Tertiary formations were dissected during the first major advance of Pleistocene continental ice. Oldest Pleistocene deposits occur in valleys cut in the Tertiary. Upper Tertiary beds attain a thickness of over 15,000 feet. No stratigraphic breaks are present, and faunal evidence does not justify differentiation into Miocene and Pliocene.

Three-dimensional information is exceptionally good, both inland and for about 30 miles offshore. Wells in the Gulf encounter the base of Recent deposits at about 550 feet, where there is a widespread oxidized zone in the uppermost Pleistocene. Pleistocene beds, with many gravel layers, extend to a depth of 2,500 feet in many wells. The Upper Tertiary reaches depths exceeding the maximum deep in the Gulf of Mexico, and consists of deltaic sediments. The first widespread marine section in inland wells occurs in the Lower Tertiary (Oligocene?).

The Pliocene-Pleistocene boundary occurs at the base of the formation deposited when the first major ice-advance began. Marine facies should occur only beyond the continental shelves. The oldest Pleistocene inland is the alluvial deposit underlying the terrace formed during the first major ice-retreat.

LOUISIANA is centrally located on the east-west coast north of the Gulf of Mexico. Structurally it lies on the north flank of the Gulf Coast geosyncline, an actively filling trough that trends in general parallelism with the coast around the entire gulf margin. Gulfward-dipping formations of the north flank outcrop across an inland belt over 300 miles in width and for distances of up to about 100 miles across a shallow-water shelf south of the shore in Louisiana.

Geophysical evidence indicates a depth of some 24,000 feet to the Tertiary-Cretaceous contact in the vicinity of Louisiana and Texas coasts. This is roughly twice as far below sea-level as the deepest part of the floor of the Gulf of Mexico. The basal layers of sedimentary rock in the geosyncline, however, are of Lower Cretaceous age, and are thought to lie as deep as 30,000 feet. An oil well nine miles offshore ends in Miocene sediments at a depth of 13,625 feet. The Queen Bess well near the coast reached a total depth of 15,523 feet, ending in Miocene, and with Miocene distillate production at 13,888 feet. Several miles to the west, petroleum is produced from the Miocene at 13,763 feet. At the time of writing a well slightly inland from the coast is testing for petroleum at a depth of 16,106 feet, in the Miocene.

The entire Gulf Coast region is highly petroliferous. Its exploitation has advanced to the point where it has become the world's most thoroughly known area from the geological standpoint. No comparable area has so many wells, so many deep wells, nor so many geologists examining cores, resistivity logs, faunas, and other aids to stratigraphic and structural fact-finding.

The record of sedimentation is continuous since the Lower Cretaceous. Though loci of heaviest sedimentation have shifted from place to place, and rates of deposition have varied from excessively heavy in Lower Cretaceous, Lower Eocene, and Miocene to Recent to moderate or rather inconsequential in parts of the Upper Cretaceous, Upper Eocene, and Oligocene, there is no true angular unconformity nor evidence of widespread erosion in the entire section. Subsidence has been the rule, at varying rates. There has been general uplift inland and maximum depression gulfward, so as to produce southward regional tilting in Louisiana. Localized areas such as the Sabine Uplift have behaved in a " positive " manner, so that they have accumulated stratigraphic sections of less than normal thickness, both as a whole and for individual formations. This " positive " behaviour has consisted mainly of subsidence at less than average rates for the surrounding area.

If the time-scale for the Tertiary were being formulated at present from Gulf Coast evidence it

would require but two divisions which could best be called Eogene and Neogene. The boundary between the two would lie at the base of the Miocene as recognized by Louisiana geologists. Below the Tertiary are thick Cretaceous sections that mark the start of Gulf Coast geosynclinal depositional patterns. The earliest thick section to accumulate is found in Florida, where the Cretaceous is at least 10,000 feet thick. More than half of that thickness occurs in north-western Louisiana.

The subsurface Eogene of Louisiana consists overwhelmingly of deltaic deposits which grade gulfward into strictly marine facies. Thickest sections are found in Texas, especially toward the Rio Grande. Wells in southern Louisiana several tens of miles inland encounter considerable thicknesses of marine sediments, but the surface outcrops in the northern part of the state are predominantly continental.

Supplies of sediment were greatly diminished in the latest Eogene. Broad invasions of the Gulf reached places now far inland. An abundance of marine fossils encourages geologists and paleontologists to subdivide this part of the section into extremely small units, but the total volume of Claiborne, Jackson, and Vicksburg deposits is really minor in comparison with either the rest of the Eogene below or of the Neogene above.

Neogene sedimentation was heaviest in Louisiana. Practically all of the section, even in subsurface many miles into the Gulf, is deltaic in origin. Petrified wood, beds of lignite and closely associated glauconite, and considerable quantities of volcanic ash characterize much of the deposit. A few thin wedges containing marine microfaunas are extremely useful marker horizons, but there are no thick and extensive layers containing marine shells or that may be considered as of strictly marine origin. Some 10,000 feet and more of subsurface section consists of comparatively thin layers of sandstone, siltstone, and clay, alternating irregularly and quite barren of fossils. The locus of deposition lay offshore with reference to existing coasts of Louisiana and Texas. Stratigraphic continuations of Louisiana formations, followed eastward along the strike, exhibit marine facies in Alabama and Florida.

Though attempts to recognize traditional Tertiary epochs are the rule, no one has yet discovered a rational basis for distinguishing between Miocene and Pliocene in the Gulf Coast region. By custom some inland beds have been called Pliocene, but these contain basal gravels of definite Pleistocene age. The Louisiana Geological Survey recognizes no Pliocene outcrop within the state, nor has it found any basis for dividing the subsurface Neogene deltaic deposits into parts which might appropriately be assigned to the Pliocene epoch.

The " Pliocene-Pleistocene " boundary in the Gulf Coast region is really a Neogene-Quaternary boundary. The pattern of heavy Neogene deposition continues into the Quaternary, but oscillations in sea-level associated with growths and declines in amounts of continental ice introduce sharp breaks in depositional patterns.

Neogene deposition ended with the advent of the first major glaciation. The level of the Gulf of Mexico was lowered enough to drive the shoreline some 100 miles southward from the coast of western Louisiana. The magnitude of the drop is not known exactly, but may be presumed to have been in the order of 400 feet. The evidence in favour of this presumption is the thickness of the earliest Pleistocene formation inland, a deposit formed during the rise in Gulf level following the first major glaciation. The earliest Pleistocene formation has a thickness along inland stream valleys that closely approximates that of the Recent. The evidence that the Recent deposits accumulated during a rise of about 400 feet in Gulf level is positive (Fisk, 1944).

Prior to the earliest glaciation there had been no Mississippi River or other stream that concentrated the drainage of such a vast area into a single channel leading toward the Gulf of Mexico. The task of draining the region between the summits of the Appalachians and those of the Rockies fell to many rivers, no one of which approximated the Mississippi in volume or transporting ability. Prior to lowering of the Gulf during the several glacial stages of the Pleistocene little gravel found its way southward to Louisiana. With increased gradients of streams and the concentration of discharges into the Mississippi channel came tremendous volumes of coarse gravel not only to what is now inland Louisiana but also to sites of deposit many miles beyond the coast.

PART IX: THE PLIOCENE-PLEISTOCENE BOUNDARY

While at some distance out in the Gulf of Mexico there may be a rather continuous record of deposition of marine beds, the area of the shelf and all places inland experienced extensive exposures to subaerial agencies of erosion during each Pleistocene glacial stage. Each was a halt in deposition, a hiatus in the depositional record. Deep valley systems were formed during each lowering of sea-level. Valleys excavated during waxing glaciations were filled by sediments during the rise in sea-level accompanying each stage of waning glaciation.

The Neogene-Quaternary boundary in inland situations lies immediately below the oldest Pleistocene formation, at the contact between the oldest terrace deposit and the bedrock. The earliest Pleistocene, however, was a time of widespread erosion and roughening of the topography. Contemporaneous with these erosional activities was the deposition of deltaic material along a coast far to the south, and of marine sections beyond the edge of the shelf. Gravels were being carried across the shelf. During the wane of the earliest continental ice and general rise in Gulf level the locus of deposition of basal gravels moved inland. The contact between earliest gravels and the underlying bedrock in an inland situation actually represents a time somewhat later than that between gravel and underlying rock out on the shelf. The best examples of the physical boundary at the base of the Pleistocene are the lowermost gravel contacts farthest out on the shelf. Fortunately the records in oil wells are clear-cut and positive.

There were five major lowerings and risings of sea-level during the Quaternary. The deposits that accumulated inland during the first four rises are regarded as Pleistocene, and are known as the Williana, Bentley, Montgomery, and Prairie formations in Louisiana. The upper surfaces of these formations form terraces that are clearly differentiated to-day because gulfward tilting was in progress throughout the Quaternary. The fifth general rise in sea-level has been accompanied by the deposition of the Recent formation. The basal gravels of the Quaternary formations have been correlated for considerable distances both inland and across the shelf.

The most remote well on the shelf to-day lies 27 miles from the nearest land, in water about 20 feet deep. This well reached a depth over 2,000 feet below the bottom of the deepest water in the Gulf of Mexico. In the present connection, however, our interest lies in the fact that sharp breaks were found at the base of the Recent and the base of the Pleistocene.

The base of the Recent is an extremely sharp contact in the subsurface sections of all wells in coastal Louisiana and on the shelf. The break is between an overlying section of wholly unoxidized material and a layer that is thoroughly oxidized. Greyish, bluish, and black sediments containing many layers of Recent shells overlie reddish and yellowish beds containing limy nodular materials. The period of oxidization was that of the last general low-stand of the Gulf, or latest widespread continental glaciation. It has been possible to prepare maps showing details of latest Pleistocene topography across most of coastal Louisiana and at various places on the shelf because the first appearance of oxidized materials is so sharp in cores from borings. These maps have been issued by the Mississippi River Commission. Most wells on the shelf encounter the base of the Recent at a depth of about 550 feet.

The basal Pleistocene gravels, which occur at an elevation of about 450–500 feet above sea-level in the northern parts of the lower Mississippi Valley, continue southward to a level of about 2,500 feet below sea-level on the Louisiana shelf. If we assume that the outermost gravels were deposited some 400 feet lower than Gulf level to-day, there has been a subsidence of about 2,000 feet of the Neogene-Quaternary contact.

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THE PLIOCENE-PLEISTOCENE BOUNDARY AND GLACIAL CHRONOLOGY BASED ON EUSTASY IN THE EAST INDIES*

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ABSTRACT (WITH TABLE)

A critical examination of the existing principles used to demarcate the Pliocene-Pleistocene boundary in the East Indies, viz. (1) the tectonic principle, (2) the principle of Deshayes, (3) the principle of the water-content of brown coal, (4) the principle of foraminifera, (5) the principle of vertebrates—shows that only the last principle enables one to obtain an exact demarcation.

Vertebrate remains, however, are relatively seldom found, especially in oceanic islands, and up till now only known from Java and some other localities in the Archipelago. Therefore a sixth principle has been introduced, viz. *the principle of glacial chronology based on eustasy*. The author lately succeeded in identifying the Pleistocene eustatic shifts of sea-level in Java and Sumatra, establishing a new glacial chronology based on eustasy. In Java this chronology appears to be quite in harmony with Pleistocene stratigraphy, based on vertebrate palaeontology; in Sumatra, where vertebrate remains are lacking, it shifts the Pliocene-Pleistocene boundary considerably downward, involving exactly the same stratigraphic rejuvenation as in Java since the introduction of the principle of vertebrates. (cf. Table).

Glacial chronology based on eustasy affords a new principle to establish the Pliocene-Pleistocene boundary with great accuracy, implying moreoever a strict synchronism, which is not the case if other principles are used.

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* Published in full in *Verhandelingen Ned. Geologisch-Mijnbouwkundig Genootschap*, 1949, Geologische Serie dl. 15, p. 1–31.

TABLE OF GLACIAL CHRONOLOGY IN JAVA AND SUMATRA

Stratigraphical column			Glacial column	Time column in years	Eustasy	Java		South and Central Sumatra	North Acheen	East Acheen
	India	Java								
Recent			Post-glacial stage	25,000	—	slight recent dissection of the low terrace				
Holocene					+	deposition of the low terrace				
PLEISTOCENE	POTWAR	NGANDONG	Würm-regression	100,000	—	dissection of the high terrace, trenching of wide deep valleys, still continuing as submarine valleys at the bottom of the Soenda Sea				
			3rd interglacial transgression	55,000	+	deposition of the high terrace (on Java with Ngandong fauna)				
						Unconformity				
	NARBADA	TRINIL	Riss-regression	60,000	—	DJOMBANG BEDS	dissection of the terraces with Trinil fauna	Upper Palembang b	Tuffsandstone Zone	
			2nd interglacial transgression	185,000	+	KABOEH BEDS	deposition of the terraces with Trinil fauna	Upper Palembang a		
	UPPER BOULDER CONGLO-MERATE		Mindel-regression	55,000	—		dissection of the terraces with Djetis fauna	Middle Palembang b	Brown Coal Zone	Djoelo Rajeu Horizon
	LOWER BOULDER CONGLO-MERATE	DJETIS	1st interglacial transgression	60,000	+	POETJANGAN BEDS	deposition of the terraces with Djetis fauna			
	BAIN BOULDER BED		Günz-regression	60,000	—		dissection of the Pliocene terraces	Middle Palembang a		
PLIOCENE	PINJOR	KALI GLAGAH				Kalibeng beds		Lower Palembang	Operculina Zone Main Fossil Horizon	Seuroela Horizon

THE PLIOCENE-PLEISTOCENE BOUNDARY IN THE GREAT PLAINS REGION OF NORTH AMERICA

By THOMPSON M. STOUT

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(SUMMARY OF REMARKS CONTRIBUTED AT JOINT MEETING OF SECTIONS H AND K)

ON behalf of a group of workers in another part of the world from that so far considered in these meetings, I would like to direct attention to the critical importance of the Great Plains region of the United States in determining the Pliocene-Pleistocene boundary in North America.* The states of Nebraska, Kansas, and South Dakota are so situated that Early Pleistocene glaciers penetrated into their eastern areas, and the relation of these glaciations to the magnificent Tertiary succession of mammal-bearing continental sediments can be determined.

In Nebraska, the University of Nebraska (including the divisions of the Nebraska Geological Survey, University of Nebraska State Museum, and Department of Geology) and other co-operating institutions have been for many years actively engaged in working out the relations between these earliest glacial deposits and the Pliocene sediments of western and central Nebraska. The deposition of the latest Ogallala Group or Pliocene sediments in western Nebraska concluded the long, chiefly aggradational, history of the Tertiary. In the upper Ogallala sediments are found fossil mammal remains which are regarded by Dr. C. Bertrand Schultz and the present speaker as of definite Astian type. Following uplift (accompanied perhaps by slight folding) of these Ogallala or Pliocene deposits, streams cut new valleys. In these valleys there were deposited a basal gravel, an intermediate marl-peat bed with loess-like silts, and an upper gravel. It is the present opinion of Nebraska geologists and paleontologists that this intermediate bed (termed the Lisco member of the Broadwater formation) can be considered as the probable equivalent of the Fullerton clay (demonstrably Aftonian or First Interglacial) of the eastern half of Nebraska. The Lisco member in western Nebraska yields a very rich assemblage of fossil mammals which Dr. Schultz and this speaker regard as of Villafranchian type. Present evidence in Nebraska, then, suggests that the Villafranchian equates in part with the Aftonian or First Interglacial, while the Cromerian equals the Yarmouth or Second Interglacial.

Much work in critical areas in France is now in progress by a number of individuals and institutions. Particular mention should be made of the splendid work being done by Dr. Jean Viret and his collaborators in the study of the St. Vallier deposit near Lyon, and of the magnificent contribution being made by Dr. Samuel Schaub of Basle in his long-continued investigation of the classic Montagne de Perrier locality. For Africa, the long-awaited report by Prof. Camille Arambourg on his studies of the remarkable Abyssinian deposits and their Villafranchian mammals has now appeared.

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* See the results of the conference on the Pliocene-Pleistocene boundary in the Great Plains held in Chicago in December, 1946, published as a Symposium on the Pleistocene of the Great Plains in the June, 1948, issue of the "Bulletin of the Geological Society of America."

FORAMINIFERAL EVIDENCE FOR PLIOCENE-PLEISTOCENE BOUNDARY

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ABSTRACT

Micropalaeontological analysis of marine sediments of Pliocene and Pleistocene age has so far shown that only a few genera of Foraminifera are restricted to either of the two formations. Representatives of the following Pliocene genera, so far not recorded from older or younger beds, are: *Asanonina*, *Dyofrondicularia*, *Epistominella*, *Hanzawaia*, and *Parafrondicularia*. Restricted to Pleistocene are: *Bifarinella*, *Geminospira*, *Oolitella*, *Polymorphinoides* and *Unicosiphonia*. Together with species of the last-named five genera, the presence of the representatives of the following genera, which range from Pliocene to Recent, indicates Pleistocene age: *Candeina*, *Cribolinoides*, *Cushmanella*, *Cribrobulimina*, *Hippocrepina*, *Planopulvinulina*, *Planulinoides*, *Poroeponides*, *Pseudononion*, *Pyrgoella*, *Schlumbergerina*, and *Torresina*.

Where Pliocene and Pleistocene sediments are present in brackish-water facies, a separation of the two formations will be difficult, as both of them carry *Rotalia (Streblus) beccarii* L., miliolids, and a few other forms which can adapt theirselves to brackish water conditions. In such cases paloecological studies will reveal possibilities for a separation of the two formations (warm and cold water influences, increase or decrease of salinity, etc.) If continental beds prevail in both formations palynology will be the method of choice.

More faunal-analytical studies of Pliocene and Pleistocene beds are needed in order to ascertain the diagnostic foraminiferal assemblages of each formation, both from a qualitative and quantitative point of view.

CORRELATION BETWEEN THE PLIO-PLEISTOCENE DEPOSITS IN EAST ANGLIA AND IN THE NETHERLANDS

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ABSTRACT

In ascertaining the Plio-Pleistocene boundary, facts which are a result of a colder climate should be considered first. This boundary has only an epoch value. Consequently the terms Tertiary and Quaternary should be abandoned. The best way to obtain a final and general Plio-Pleistocene stratigraphy is to proceed from correlations based on the study of periglacial districts. Free use of local names which gradually might disappear is to be preferred rather than uncertain squeezing in a general nomenclature. Interpretation of the curve of Milankovitch should be avoided. A quantitative research of foraminifera from the Crags showed me that (1) the Butleyan is characterized by a sudden upward jump in the number of arctic species, (2) in the North Sea occurred a regression during the Butleyan, followed by a transgression in the Upper Norwichian. Therefore it would be consistent to draw the Plio-Pleistocene boundary between Newbournian and Butleyan. Other arguments in favour of this view are (1) the alternation of the predominance of southern molluscs in that of northern during the Butleyan and (2) the first appearance of elephants (*Archidiskodon planifrons*) in the Butleyan of the Netherlands.

It is generally recognized that the Pleistocene and the Ice Age, or Glacial Epoch, are synonymous, which implies that the Pleistocene must have begun at the first onset of cold conditions at the end of the Cainozoic. Such a boundary is, surely, only that of an epoch, and not of a period. Consequently the terms " Tertiary " and " Quaternary " should be abandoned (Flint, 1947). A second reason for taking such action is shown by the illogical references still made to the already abandoned terms " Primary " and " Secondary," names not even of periods but of eras. In ascertaining the first appearance of the incoming colder conditions a study of marine deposits seems most desirable. A sudden increase in the number of arctic species in a deposit at once suggests the beginning of a glacial phase. In tropical regions, however, this phenomenon is not to be expected, so that evidence in these areas for the beginning of the Glacial Epoch would have to depend on a study of a regression of the sea.

In fixing the boundary between the Pliocene and Pleistocene, a succession of deposits such as those found in East Anglia and the Netherlands is essential. In these areas both marine regressions and the sudden advent of cold species can be studied. At the same time it is possible to make correlations between marine and continental deposits where they interdigitate. This implies an establishment of palaeontological characteristics of the Plio-Pleistocene continental beds. These in their turn will be of use in determining the age of continental deposits in other areas. It is clear then that for the time being the use of local names will be unavoidable, but these will gradually fall into disuse. The free use of local names is to be preferred rather than squeezing them into uncertain positions in a general nomenclature.

The use of the insolation curve of Milankovitch for fixing the boundary between the Pliocene and Pleistocene and for subdividing the Pleistocene should be avoided. Flint (1945) has already published seven objections to this hypothesis. One more could be added. When the curve of Spitaler (1939), based on the variations in the eccentricity of the earth's orbit, is compared with that of Milankovitch it is impossible to find a clear agreement. The greatest difficulty in the use of these curves is, however, the fact that they can be interpreted in such different ways. After Spitaler (1939), the beginning of the Günz glaciation should be set at 1,306,950, after Eberl (1930) at 763,000, after Köppen and Wegener (1924) at 594,000 and after Gams (1937) at 238,000 years, before the present day. According to these authors the duration of the Riss should be put at respectively 195,000, 11,000, 53,000, and 8,000 years.

CORRELATION BETWEEN PLIO-PLEISTOCENE DEPOSITS IN EAST ANGLIA AND THE NETHERLANDS

RE-GRES-SION / TRANS-GRES-SION	CLI-MATE	EAST ANGLIA	THE NETHERLANDS		PALAEONTOLOGICAL CHARACTERISTICS: MARINE FACIES	PALAEONTOLOGICAL CHARACTERISTICS: CONTINENTAL FACIES	PLIO-PLEISTOCENE BOUNDARY AS PROPOSED BY:
	TEM-PERATE	CORTON BED	NEEDIAN	IN W. AND N.W. THE SO-CALLED „MARINE HIGH TERRACE" IN E. THE CLAY OF NEEDE. IN S. VALLEY CUTTING (VENLO-STAMPROY).	Macoma balthica (L.) and Cardium edule L. common.	Viviparus diluvianus (L.) and Azolla filiculoides Lmk common Hesperoloxodon antiquus (Falc.) Primitive species of Arvicola.	
	COLD	NORTH SEA DRIFT	UPPER TAX-ANDR-IAN	ZONES OF STERKSEL - BUDEL-WOENSEL-WEERT		Viviparus diluvianus (L.) together with Viviparus glacialis (Wood). Azolla filiculoides Lmk. together with Azolla tegeliensis Florsch. Mimomys intermedius Newton	
?	TEM-PERATE	YOLDIA MYALIS B. CROMER FOREST B.	MIDDLE TAX-ANDR-IAN				W.B. Wright
	COLD; TEMPERATE	WEY-BOURNIAN	LOWER TAX-ANDR-IAN	„LOWER FINE SEDIMENTS" Boring Schoorl marine „Icenian"	Elphidiella arctica P. et J. (60% of foram. fauna). Cibicides lobatulus (W. et J.) (15% of foram. fauna). First appearance of Macoma balthica (L.) (abundant).		
	TEM-PERATE	CHILLES-FORDIAN	UPPER TIGLIAN	In S.E. and S. clay of Tegelen:	Elphidiella arctica P. et J. (28% of foram. fauna). Cibicides lobatulus (W. et J.) (11% of foram. fauna). Polinices catena (Da.C.) (abundant).	Viviparus glacialis (Wood) and Azolla tegeliensis Florsch. common. Archidiskodon meridionalis (Nesti) Mimomys pliocaenicus Forsyth Major	
		NORWICHIAN UPPER	UPPER TIGLIAN	clay-pits near Tegelen / In W. and N.W. marine „Icenian"	Elphidiella arctica P. et J (59% of foram. fauna). Cibicides lobatulus (W. et J.) (14% of foram. fauna). Natica subtruncata Da.C. and Polinices catena (Da.C.) abundant.		
		NORWICHIAN LOWER	LOWER TIGLIAN	clay-pit near „Bovenste Molen"			P. Tesch
	COLD	BUTLEYAN	PRAETIGLIAN	BLACK BONES DEPOSIT IN EASTERN-SCHELDT. IN W. AND N.W. MARINE „AMSTELIAN"	Elphidiella arctica P. et J. (72% of foram. fauna). Cibicides lobatulus (W. et J.) (7% of foram. fauna). Serripes groenlandicus (Brug.) Natica clausa (Brod. et Sow.) and Neptunea despecta (L.) abundant.	Archidiskodon planifrons (Falc. et Cautley). Trichechus huxleyi (Lmk.)	the author
	TEMPE-RATE-WARM	NEW-BOURNIAN	REUVERIAN	IN S.E. CLAY OF REUVER AND BRUNSSUM, SILICEOUS OÖLITES. IN W. MARINE „POEDERLIAN"	Elphidiella arctica P. et J. (5% of foram. fauna). Cibicides lobatulus (W. et J.) (42% of foram. fauna). Natica millepunctata multipunctata Wood abundant.	Sequoia, Liquidambar, Nyssa	

FIG. 1.

The accompanying correlation table (Fig. 1) is *inter alia* based on the results of a statistical research on the foraminifera from the marine deposits of East Anglia (Kendall, 1931) and the Netherlands. This research was partly the work of Ten Dam and Reinhold (1942), and partly that of myself from samples collected by C. D. Ovey and myself in Norfolk and Suffolk. In the Poederlian of the Netherlands the Mediterranean species *Cibicides lobatulus* is prominent, forming 40–45 per cent of the total foraminiferal fauna. The arctic form *Elphidiella arctica* is represented by only 2–8 per cent. The Amstelian of the Netherlands is, according to Ten Dam and Reinhold, characterized by 50–70 per cent *Elphidiella arctica* (*E. hannai* included) and 15–20 per cent *Cibicides lobatulus*. From the Icenian of Holland they mention only 30–50 per cent, or slightly more, of *Elphidiella arctica*. In a boring near Schoorl (on the N.W. coast of Holland) at a depth of between 862 and 954 feet, representing the top of the Icenian, Tesch (1947) found a fauna with 60 per cent *Elphidiella arctica*.

In the transition beds between the Newbourian and Butleyan (¼ mile W.N.W. of Ramsholt Church, Suffolk) of East Anglia, I found 33 per cent *Cibicides lobatulus* and 48 per cent *Elphidiella arctica*. It forms a typical transition-sample between those from the Poederlian and those of the Amstelian of the Netherlands. From the Butleyan I got two samples, one from Neutral Farm and one from Virtue's Farm, Hollesley, Suffolk, with respectively 74 and 77 per cent *Elphidiella arctica*, 8 and 5 per cent *Cibicides lobatulus*. A correlation with the Amstelian of the Netherlands is justified. From the Norwich Crag a sample was collected from Bramerton, a hamlet 4½ miles S.E. of Norwich, with a percentage of 55 per cent *Elphidiella arctica* and 1½ per cent *Cibicides lobatulus*; and one at Kirby Bedon, near by, with 62 per cent *Elphidiella arctica* and 14 per cent *Cibicides lobatulus*. These can be correlated with the lower part of Ten Dam and Reinhold's Icenian. A sample from the Chillesfordian collected by C. D. Ovey near Chillesford Church, yielded 28 per cent *Elphidiella arctica* and 11 per cent *Cibicides lobatulus*. This represents the middle, warmer part of the Icenian. From the Weybournian, Macfadyen (1932) described a sample from the lowest 2 feet of Crag, overlying Chalk (coast section, Weybourne), with mainly *Elphidiella arctica* (60 per cent), and 15 per cent *Cibicides lobatulus*. It will be the equivalent of the upper part of the Dutch Icenian, such as was described by Tesch (1947) from the boring near Schoorl.

The correlation between the marine beds of East Anglia and the Netherlands thus obtained makes it possible to judge more exactly the conditions of life on the continent during the end of the Pliocene and the beginning of Pleistocene in these districts. Any direct comparison between continental beds in East Anglia and those in the Netherlands has always been hindered by the fact that most of the fossil mammal remains found in East Anglia have come from the so-called stone-beds at the base of the Crags. The possibility that many of them are secondarily deposited is no figment of the imagination, but from the Dutch localities this is most improbable.

I use the name Reuverian for the equivalent of the Newbournian in East Anglia, because I believe that the clay of Reuver, well known through the description of its flora by C. and E. Reid (1915), corresponds in age with the marine Poederlian of Ten Dam and Reinhold. At Brunssum, in the southern part of Limbourg, this clay is intercalated with a sandy deposit, the so-called siliceous oolite-beds. In his thesis for the doctor's degree at the University of Leyden, Van Straaten (1946) showed that these siliceous oolite-beds must have been formed during a temperate-warm climate just before the beginning of the Pleistocene period. His arguments are: (1) the high degree of chemical weathering apparent from the total absence of felspar-bearing stones and (2) the low degree of physical weathering apparent from the very small percentage of broken flint pebbles (fragmentation caused by freezing).

Botanical research on the clay of Reuver by Florschütz and Van Someren (1948) confirmed the results of Mr. and Mrs. Reid, that *Sequoia* (mammoth-tree), *Liquidambar* (amber-tree), and *Nyssa* are the most characteristic plants.

The deposit of the " black bones " found in the Eastern Scheldt (Van der Vlerk, 1938) is characterized by the presence of the first elephants in this district: *Archidiskodon planifrons* (Schreuder, 1944), accompanied by *Anancus arvernensis*, *Cervus falconeri* and a walrus, *Trichechus huxleyi*. The presence of the walrus makes it probable that this fauna lived after the warm Reuverian times. The ash

percentage of these bones seemed to be higher than that of all other Cainozoic bones found in the southern part of Holland (Van der Vlerk, 1938). This fauna therefore must be older than the fauna of Tegelen. Again, the animals must have lived after the Reuverian and before the Tiglian, during an age which I propose to call the Praetiglian, which is equivalent to the Butleyan stage of the East Anglian Crags and the marine Amstelian of the Netherlands.

Lately Miss Schreuder (1945) gave another survey of the remains of mammals collected from the clay of Tegelen. All of them are found in the clay-pits which are situated in the village of Tegelen (Latin: *Tiglia*). Until recently there has been no systematic collecting from these pits. A first endeavour in this direction has already shown that in the higher part antlers (*Cervus tegeliensis*, *Cervus rhenanus*) especially are found, and that the remains of *Conodontes boisvilletti* occur in the lower parts at Tegelen and in a pit further to the north (Bovenste Molen) in the neighbourhood of Venlo. This last mentioned clay is at a lower level than at Tegelen. It is here that Florschütz and Van Someren (1948) record a late Pleistocene cryoturbate structure in the clay, caused by thawing of a " perpetually " frozen ground. From pollen-analysis these authors concluded that most of the lower part of the clay at Bovenste Molen and the upper part of the clay at Tegelen must have been deposited during a rather cold climate. The analysis and the cryoturbate structure give the impression that the same fluctuation of temperature which is known from the marine Norwichian-Chillesfordian is also reflected in the continental deposits. Palaeontologically these deposits are characterized by the presence of *Mimomys pliocaenicus*, *Archidiskodon meridionalis*, and a relative abundance of *Viviparus glacialis* and *Azolla tegeliensis*.

The age, indicated in the correlation-table (Fig. 1) as Taxandrian, is clearly limited both by its lower and upper boundaries. During this stage, beds which overlie the clay of Tegelen, and underlie the clay of Neede, were deposited. Contemporaneous deposits in East Anglia can be divided into three parts, of which the Weybournian and the North Sea Drift represent the cold phases. In his thesis for the doctorate of the University of Leyden, Zonneveld (1948) made a sedimentary petrological research on beds of this age in Holland. His " lower fine sediments " were in all probability formed during the Weybournian. In the middle and upper parts of the Taxandrian coarse sands are found containing garnet, epidote, hornblende, and saussurite (Zones of Sterksel, Woensel, and Weert). These deposits mark the courses of the Rhine of those times. Other sands are characterized by the presence of tourmaline, zircon, rutile, staurolite, kyanite, andalusite, turbid chloritoid, brown-grey hornblende, and sometimes turbid garnet (Zone of Budel). They are a deposit of a former Meuse. Palaeontologically these deposits are found to be characterized by the simultaneous occurrence of *Viviparus glacialis* and *V. diluvianus*, of *Azolla tegeliensis* and *Azolla filiculoides*, and the presence of *Mimomys intermedius*.

The clay of Neede (a village in east Holland) is palaeontologically characterized by an abundance of *Viviparus diluvianus* and *Azolla filiculoides*, the presence of an elephant with still more developed molars, *Hesperoloxodon antiquus*, and the first appearance of the still living red deer (*Cervus elaphus*) and water-rat (*Arvicola*). While this freshwater deposit was being laid down in the eastern, western, and northern parts of the Netherlands, marine beds were being deposited in the northern part of East Anglia, and in the western and northern part of Holland. In England these are called the Corton Beds (Baden-Powell and Reid Moir, 1942), and in Holland they received the peculiar name of " Marine high-terrace " (Tesch, 1942). A. Brouwer, who was the first to advocate the synchronous deposition of these freshwater and marine deposits, is discussing the problem in a thesis he is presenting in September 1948 to the University of Leyden. Both in East Anglia and in the Netherlands this period was characterized by a high degree of valley-cutting (valley of Stamproy-Venlo in the northern part of Limbourg).

In order to draw a boundary between the Pliocene and Pleistocene from the evidence here discussed, it is necessary to take into account the geographical distribution of the deposits. The seven palaeographical maps shown here (Fig. 2) were constructed largely from the researches of geologists in the Dutch Geological Survey (Ten Dam and Reinhold, 1942; Tesch, 1942). The large regression indicated by map IV suggests the beginning of the Glacial Epoch (Wright, 1937). On closer inspection of the physiographical changes in the North Sea area, however, it is clear that there were two even earlier

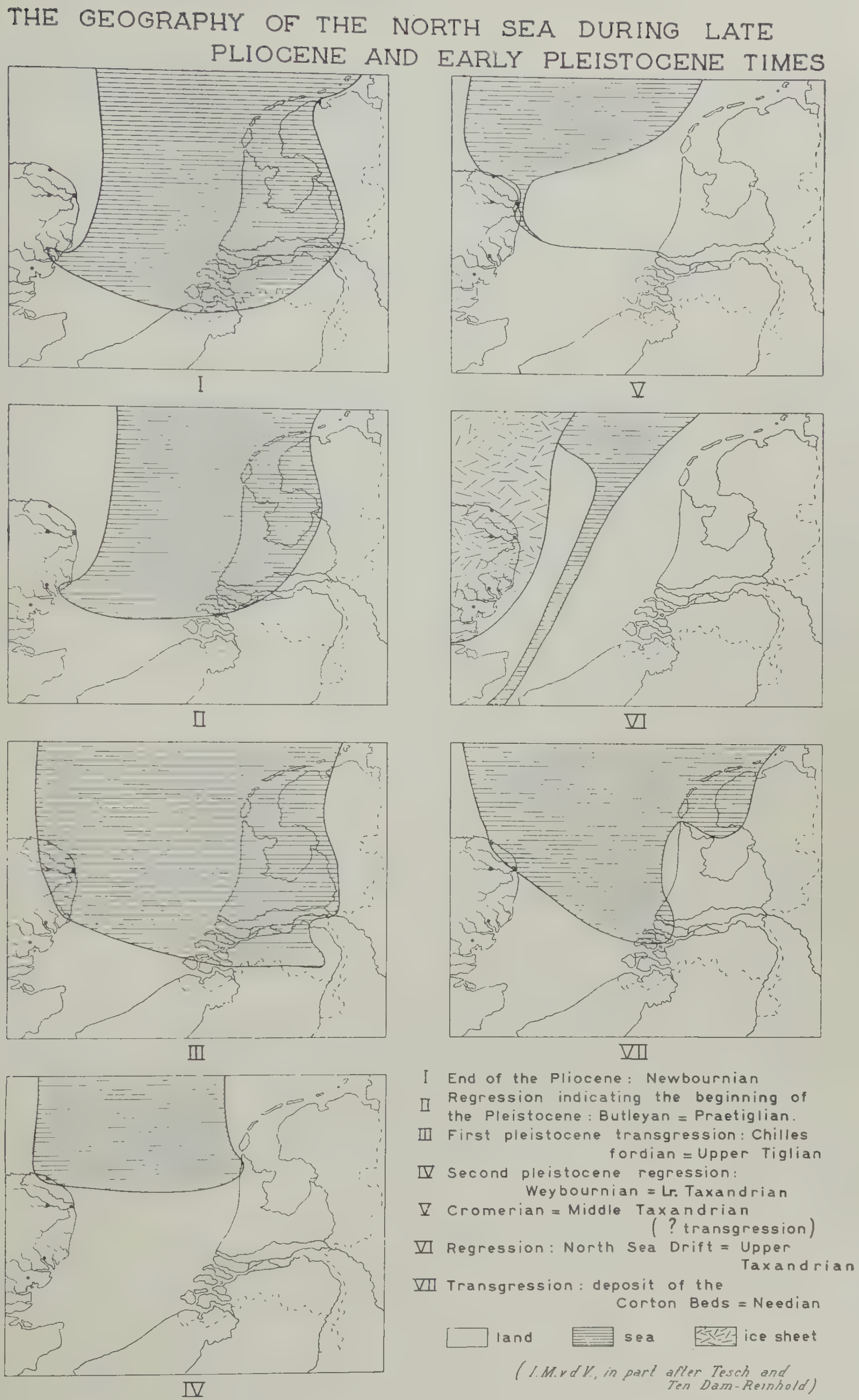
THE GEOGRAPHY OF THE NORTH SEA DURING LATE PLIOCENE AND EARLY PLEISTOCENE TIMES
I
V
II
VI
III
VII
IV
I End of the Pliocene: Newbournian
II Regression indicating the beginning of the Pleistocene: Butleyan = Praetiglian.
III First pleistocene transgression: Chillesfordian = Upper Tiglian
IV Second pleistocene regression: Weybournian = Lr. Taxandrian
V Cromerian = Middle Taxandrian (? transgression)
VI Regression: North Sea Drift = Upper Taxandrian
VII Transgression: deposit of the Corton Beds = Needian
land
sea
ice sheet
(I.M.v.d V., in part after Tesch and Ten Dam-Reinhold)

FIG. 2.

regressions (maps II and IV). The first of these coincided with the sudden influx of arctic forms in the foraminiferal and molluscan faunas, while the contemporaneous continental fauna was marked by the appearance of the first elephants in Western Europe (Boswell, 1931 and 1940; Pilgrim, 1940 and 1944; Cooke, 1948; Zeuner, 1945). It is, therefore, logical to conclude that this is the proper place to draw the boundary, that is, at the commencement of the Butleyan (= Praetiglian) times. In so doing the boundary is still somewhat lower than that proposed by Tesch (1947), who considered the Icenian as the beginning of the Pleistocene. Both he and Ten Dam and Reinhold (1942) also remarked that the Icenian was a period of transgression, following the regression of the North Sea during the Amstelian. One cannot accept, however, a period of transgression to coincide with the beginning of a glaciation when an ever increasing volume of water was being held fast in a solid state by the process of freezing.

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THE TRANSITIONAL PASSAGE OF PLIOCENE INTO PLEISTOCENE IN THE NORTH-WESTERN SUB-HIMALAYAS*

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ABSTRACT

The heavily sedimented tract of country of Hazara—Punjab Sub-Himalayas, with its pile of over 30,000 ft. of fluviatile, fluvio-glacial and subaerial sediments, contains one of the most complete and copious records of Mio-Plio-Pleistocene. This is a well-bedded and continuous sequence with insignificant local breaks containing, at several horizons, abundant mammalian fossils to enable a classification into stages. The thesis of this paper is that nowhere in this pile of sediments is a definite natural Pliocene-Pleistocene boundary discernible. The succession in two type areas is described: (i) The Soan Valley syncline and (ii) sections in the Pir-Panjal range in Kashmir, where the ice-age deposits rest conformably over lacustrine deposits containing *Elephas hysudricus*.

This stratigraphic record is unique in being concurrent and synchronous with the tectonic history of the later phases of Himalayan uplift, the onset and progress of the first two glaciations of the Himalayan ice age, and the development, spread and extinction of the wonderfully prolific Siwalik mammalian fauna preserved in the beds, abounding in remains of all the higher mammals except man. Deposition during this interval went on uninterrupted and has preserved a complete register of these interesting events.

* This paper was read at the joint meeting with Section K held on Aug. 28th, and is printed in full in Part XI of the Report.

DIE GRENZE PLIOZÄN-PLEISTOZÄN IN EUROPA

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ABSTRACT

The characteristic phenomena of the Pleistocene are the glaciations, i.e., world-wide climatic events. The lower boundary of the Pleistocene should be placed with the beginning of the climatic change which led to the first big regional glaciations. A review of the Pliocene-Pleistocene boundary in the various regions shows that in certain cases this boundary can be drawn rather exactly, but in other cases this is not possible. In the Alps there are some dubious pre-Günz glaciations (" Donau-glaciations ") which need further investigation. In the periglacial area of Middle Europe several " preglacial " river terraces antedate the first northern ice invasion and are uncertain in their age. In the area of the North European glaciation the question of an oldest pre-Elster glaciation (= Günz of the Alps?) is not yet solved. If the arctic shells of the Upper Crag (especially the Weybourne Crag) of East Anglia mark a first northern glaciation and the Cromer Forest Bed is an interglacial deposit, then we find a relatively high ocean level during a glacial phase, a relatively low level during the following interglacial phase—a phenomenon not in accordance with the glacial eustatic theory.

DIE eigentlich charakteristischen Erscheinungen des Pleistozäns, um derentwillen man es vom Pliozän abgetrennt hat, sind *die grossen Vereisungen*, die sich in diesem Abschnitt der Erdgeschichte in weiten Gebieten der Erdoberfläche entwickelt haben. Es sind also weltweite klimatische Ereignisse, die man hier zur Trennung benutzt hat. Die untere Grenze des Pleistozäns sollte so gelegt werden, dass der Beginn des klimatischen Umschwungs, der zum ersten Auftreten grosser regionaler Vereisungen führte, auf jeden Fall im Quartär liegt. Dieser Bedingung würde nach den bisherigen Erfahrungen im Grossen und Ganzen eine Lage der Grenze Pliozän-Pleistozän gerecht, die nahe unter der Günzeiszeit gezogen würde. Diese Grenze ist schon vor 50 Jahren von James Geikie angenommen worden. Mit ausführlicher geologischer und paläontologischer Begründung kommt G. Pilgrim (1944) zu einer ähnlichen Grenzziehung. Sie wird auch von F. Zeuner in seinen zusammenfassenden Werken (1945, 1946) zugrundegelegt; ja, dieser möchte, fussend auf der Strahlungskurve von Milankovitch (1941), die feste Zahl von 600,000 Jahren vor der Gegenwart für die Grenze Pliozän-Pleistozän festlegen.

Eine solche Grenzziehung kommt der bisherigen landläufigen Auffassung sehr nahe. D.h. es bleibt im allgemeinen beim Pliozän und beim Pleistozän das, was man bisher in diese Formationen gestellt hat. Im einzelnen freilich ergeben sich noch manche Schwierigkeiten und Unstimmigkeiten, die erneute Untersuchungen notwendig machen. Eine regionale Betrachtung—die sich allerdings in der Hauptsache nur auf *Europa* beziehen kann—wird dies zeigen.

Verhältnismässig klar liegen die Dinge im grössten Teil der Alpen. Die Grenze gegen das Tertiär wurde hier logischerweise vor die Günzvereisung gelegt, wobei allerdings im einzelnen strittig blieb, wieviel von der Prägünzzeit noch zum Quartär zu rechnen sei. Wir kommen später noch auf diese Frage zurück. Aber es steht fest, dass die Gesamtheit der festgestellten Eiszeiten ins Pleistozän gehört. Die zeitweilig von P. Beck (1933) geäusserte Ansicht, die beiden ältesten Eiszeiten (Günz und Mindel) sowie die grosse Mindel-Riss-Zwischeneiszeit gehörten ins Pliozän und seien z.T. gleichaltrig mit dem marinen Pliozän Oberitaliens, ist von ihm später (1938) wieder aufgegeben worden. Es besteht kein Zweifel darüber, dass die Deckenschottereiszeiten jünger sind als das marine oberitalienische Pliozän. Bei ihren grundlegenden Untersuchungen über die Alpenvergletscherungen glaubten Penck und Brückner (1901–1909) in den meisten Fällen eine klare Grenze ziehen zu können. So tritt nach den genannten Autoren im Rhônegebiet über dem in einem Golf bis Lyon reichenden marinen Pliozän ein oberpliozäner Quarzitschotter auf, der *Mastodon arvernensis* enthält. Er ist, wie auch das marine

Pliozän, im Alpenrandgebiet durch einseitige Hebung der Alpen schräggestellt worden. Zwischen dem Quarzitschotter und den ältesten Glazialschottern liegt nach Penck die Grenze Pliozän-Pleistozän.

Ähnlich wurden die Dinge in Oberitalien angesehen. Das marine Pliozän hört hier mit den gelben Sanden des Astians auf. Es folgen die terrestrischen Villafranchian-Schichten, Sande und Schotter mit tonigen Einlagerungen. Sie enthalten als charakteristische Form wieder *Mastodon arvernensis*, daneben gelegentlich *Elephas meridionalis*, *Equus stenonis*, *Rhinocerus etruscus*, *Hippopotamus major*. Zwischen dem Villafranchian und den ältesten Glazialbildungen der Alpen liegt nach A. Penck (Penck u. Brückner, 1901–09, s. 912) ein längerer Zeitraum, in dem die Alpen eine beträchtliche Aufwölbung erfuhren und in dem andererseits eine erhebliche Talbildung stattfand. Erst dann kam es zur ersten Vereisung (Günz).

Ein wesentlich anderes Ergebnis hatten Untersuchungen von B. Eberl (1930) im Iller-Lechgebiet des nördlichen Alpenvorlandes. Dort fanden sich Anzeichen, dass vor die Günzvergletscherung—mit zwei Hauptvorstössen—noch eine dreiteilige Donauvergletscherung zu stellen sei. Erst davor beginnt nach Eberl das Pliozän, das dort durch zwei Schotterbildungen repräsentiert ist (Staufenberg- und Ottobeurer Schotter), die sich ihrem Habitus nach wesentlich von den eiszeitlichen fluvioglazialen Schottern unterscheiden. Nach dieser Auffassung würde also die Grenze Pliozän-Pleistozän noch beträchtlich vor der Günzeiszeit liegen. Die Donau—Eiszeiten sind allerdings bisher an keiner anderen Stelle der Alpen-Umrandung wiedergefunden worden. Zeitlich entsprechende Bildungen werden aber von Soergel (1939) und Breddin (1928) in bestimmten älteren Terrassen der mitteldeutschen Flüsse erblickt (siehe weiter unten!).

Weitgehend mit der Penck-Brückner schen Grundgliederung der Alpen stimmt die Quartärgliederung in *Nordamerika* überein. Auch dort haben wir 4 Haupteiszeiten (Nebraskan, Kansan, Illinoian, Wisconsin), die sich, wie vor allem Fr. Leverett (1910) überzeugend nachgewiesen hat, altersmässig durchaus mit den in den Alpen festgestellten Vergletscherungen decken. Von älteren Kaltzeiten vor der Nebraskan-Vereisung ist in Amerika bisher nichts bekannt geworden.

In *Nordeuropa* sind bisher mit Sicherheit nur *drei* Vereisungen festgestellt worden (Elster-, Saale- und Weichsel-Vereisung der norddeutschen Bezeichnung, vgl. P. Woldstedt 1929, 1947). Die Parallelisierung mit den alpinen und den nordamerikanischen Vereisungen kann zweifellos nur so erfolgen, dass die drei norddeutschen Vereisungen den letzten drei alpinen bezw. nordamerikanischen entsprechen. Andererseits können nicht, da es sich bei den Eiszeiten um weltweite Erscheinungen handelt, in den Alpen und Nordamerika Vereisungen aufgetreten sein, während Nordeuropa eisfrei blieb. Es muss auch in Nordeuropa in dieser Epoche " Eiszeit " gewesen sein, wenn auch bisher nicht bekannt ist, in welcher Weise sie sich in Nordeuropa geäussert hat. Vielleicht bestand hier eine Vereisung, die bis ins Ostseegebiet reichte, die aber das eigentliche Norddeutschland nicht mehr oder nur ganz randlich überdeckte. Spuren einer solchen ältesten Vereisung glaubt K. Richter (1937) nachweisen zu können. Die schon lange aus Norddeutschland bekannten verkieselten Silurgerölle, deren Herkunftsgebiet Jämtland sowie Gotland und Ösel war und die meist durch pliozänen Flusstransport erklärt worden sind, möchte Richter, wie schon lange vor ihm Stolley, durch eine älteste Vereisung erklären. Ein hierfür wichtiges Profil beschreibt er aus einer Stauchmoräne südlich Stettin. Dort findet sich im Liegenden einer Quarzsand- und Kiesserie von pliozänem Habitus, d.h. mit verkieselten Silurfossilien und mit Braunkohlenbildungen, eine Spatsandserie mit nordischen Geschieben (Graniten, Porphyren, Hälleflinten u.s.w.), die man nach Richter kaum anders als durch Gletschertransport erklären kann. Dass es sich wirklich um das Liegende der " pliozänen " Quarzsandserie handele, geht nach Richter aus einem ungestörten Horizont von Windkantern hervor, die in ursprünglicher Lagerung, d.h. mit der windgeschliffenen Oberkante in den Quarzkiesen, mit der rauhen Unterseite in der Spatsandserie liegen. Bedenklich ist, dass das Profil in einer Stauchmoräne auftritt. Es ist bekannt, dass die stratigraphische Auswertung von Stauchmoränenprofilen ganz besonders schwierig ist.

Haben wir es bei der Spatsandserie wirklich mit den Ablagerungen einer ältesten Vereisung zu tun und bilden diese wirklich das Liegende der Horizonte mit verkieselten Silurfossilien, so würde daraus folgen, dass die in diese Horizonte eingelagerten Braunkohlen—so bei Stettin und im Samland—in

eine Interglazialzeit gehörten. Dagegen bestehen allerdings noch erhebliche Bedenken, und hier haben neue Untersuchungen einzusetzen, die zur Klärung dieser noch sehr umstrittenen Frage führen könnten. Jedenfalls ist in der bisher üblichen nordeuropäischen Quartärgliederung vor der bisher sicher nachgewiesenen ältesten Vereisung, der Elster-Vereisung, noch ein längerer zum Quartär gehöriger Abschnitt einzusetzen (" Präglazialzeit "), der dem ältesten Quartär des alpinen und nordamerikanischen Gebietes entspricht (Günz-Mindel-Zwischeneiszeit, Günz-Eiszeit, Prägünz-Zeit). Die Klärung der Frage einer ältesten nordeuropäischen Vereisung gehört zweifellos zu den dringendsten Aufgaben in Norddeutschland.

Zu den wenigen Flachlands-Gebieten, in denen die Grenzschichten Pliozän-Pleistozän genauer untersucht sind, gehört das mittlere Polen. Nach den Untersuchungen von J. Lewinski (1929) findet sich in dem Gebiet zwischen Warschau, Piotrkow und Lodz eine Folge " präglazialer " Schichten, die ihrerseits von der Grundmoräne der ältesten polnischen Vereisung (Cracovien = Mindel) überlagert werden. Die präglazialen Schichten bestehen aus zwei Serien, deren jede mit Kies oder grobem Sand beginnt, dann immer feinkörniger wird und mit Ton endet, der gewöhnlich Pflanzenreste, manchmal Torf- und Diatomeenreste führt. Die Kiese und groben Sande enthalten im wesentlichen von Süden kommendes, darunter einwandfrei karpathisches Material. Zweimal sind also von Süden her kräftige fluviatile Aufschüttungen erfolgt. Diese Bildungen müssen—im Gegensatz zu den gleich zu schildernden tieferen Ablagerungen, die offenbar in einem arideren Klima gebildet sind—in einem feuchteren, wasserreicheren Klima abgelagert worden sein. Die zweimalige starke Schuttbildung und Verfrachtung weist nach Lewinski (1929) auf eine doppelte Kaltzeit mit starker mechanischer Verwitterung hin. Da diese Kaltzeiten, die anscheinend durch eine wärmere Zeit getrennt waren, *vor* der Mindel-Eiszeit liegen, kann man sie vielleicht mit der Günz-Eiszeit parallelisieren, die anscheinend durch eine Interstadialzeit in zwei Vorstösse gegliedert gewesen wäre.

Unter den eben geschilderten Schichten liegt in der Warschauer Gegend der *Posener Ton*, den wir gewöhnt sind, in das Pliozän zu stellen. Ausserhalb der Verbreitung des Posener Tons treten nach J. Lewinski unter den " präglazialen " Bildungen in grossem Umfang Verkieselungserscheinungen in den höheren Niveaus auf. In den Senken finden sich in weiter Verbreitung charakteristische Ablagerungen, die aus zwei Teilen bestehen. Zu unterst liegen ausgedehnte Geröll- und Blockanhäufungen, die von einer intensiven mechanischen Verwitterung zeugen, nicht weit transportiert und wenig abgerollt sind (Serie A). Diesen Ablagerungen liegen oft sehr fette Tone auf, zusammen mit grossen Geschieben aus exotischem Gestein, mit Windschliff und einer wüstenlackartigen Kruste (Serie B). Die Schichten A und B entsprechen offenbar der oberen Partie des Posener Tons.

Alles spricht nach J. Lewinski dafür, dass in Polen die Zeit der Ablagerung des Posener Tons eine Zeit ariden Klimas war, so die Verkieselungserscheinungen an verschiedenen Gesteinen, darunter auf sarmatischem Sandstein, die äolischen Sande in den Randpartien des Posener Tones, die starke mechanische Verwitterung bei geringem Transport, der Windschliff und die Kruste an den exotischen Geröllen. Andererseits deuten die höheren, oben als " präglazial " bezeichneten Schichten auf ein wesentlich feuchteres, wasserreicheres Klima. Zweimal sind von weither, z.T. von den Karpathen, ausgedehnte Schwemmkegel bis nach Mittelpolen hin aufgeschüttet worden. An der unteren Grenze der " präglazialen " Schichten liegt ein scharfer klimatischer Umschwung. Man wird Lewinski durchaus zustimmen, wenn er hier die Grenze Pliozän-Pleistozän zieht. Die Grenze liegt also auch hier erheblich *unter* der sog. ersten nordischen Vereisung (Elster, Cracovien).

Auch aus Galizien werden die Spuren oder wenigstens die klimatischen Auswirkungen einer ältesten Eiszeit angegeben. W. Szafer (1931) beschreibt einen Torf von *Hamarnia* aus der Umgebung von Jaroslaw, der auf Tertiär liegt und von glazifluvialen Bildungen überlagert wird. Da nach allgemeiner Ansicht nur die Cracovien-Vereisung (Mindel) dies Gebiet erreicht hat, müsste der Torf älter als Mindel sein. Die Pollenanalyse zeigt aber, dass der Torf schon mit einer ausgeprägt kalten Phase beginnt. Es muss also bereits eine Kältezeit vorhergegangen sein, eine Kältezeit, die dann der alpinen Günzvergletscherung entsprechen würde, und die Szafer (1931) als Jaroslavien-Eiszeit bezeichnet. Das Pollendiagramm von Hamarnia ist recht verschieden von den zahlreichen uns bekannten

Diagrammen, die entweder in die Mindel-Riss- oder in die Riss-Würm-Zwischeneiszeit gehören. So erscheint es auf Grund des Pollendiagramms und auf Grund der Lagerungsverhältnisse durchaus als möglich, dass hier ein ältestes Interglazial (Günz-Mindel) und davor eine älteste Kaltzeit (Günz) vorhanden waren. Wir müssen demnach auch hier die Grenze Pliozän-Pleistozän beträchtlich vor die erste einwandfreie Grossvereisung Polens (Cracovien = Mindel) legen.

In Mitteleuropa gehört in die Vorstossphase der ältesten norddeutschen Vereisung (*Elster*-V.) eine ganz bestimmte Terrasse der deutschen Mittelgebirgsflüsse (" Präglaziale oder altpleistozäne Terrasse I "), die als letzte feuersteinfrei ist, während alle jüngeren Terrassen nordische Geschiebe, insbesondere nordischen Feuerstein führen. Nach den zusammenfassenden Untersuchungen von W. Soergel (1939) sind in Thüringen über der mit der norddeutschen Elstervereisung verknüpften Terrasse noch 6 " präglaziale " Terrassen vorhanden. Nach ihrer Ausbildung und ihrem Schotterbestand müssen sie, wie Soergel ausführt, unter ähnlichen Bedingungen entstanden sein wie die elstereiszeitliche Terrasse, d.h. unter *glazialen* Bedingungen. Sie unterscheiden sich dadurch von den eigentlichen pliozänen Bildungen, die meist durchaus andere Korngrössenverhältnisse und einen wesentlich anderen Verwitterungszustand zeigen.

Vergleichende Untersuchungen in anderen Flussgebieten ergaben nach W. Soergel auch für diese ein ganz ähnliches Bild. So sollen vor der norddeutschen Elstervereisung noch 6 Kaltzeiten vorhanden gewesen sein. Da die norddeutsche Elstervereisung mit Mindel II parallelisiert wird, entsprechen nach Soergel die 3 vorhergehenden " präglazialen " Terrassen (II-IV) den Kaltzeiten Mindel I, Günz II und Günz I. Diesen müssten nochmals 3 Kaltzeiten vorangegangen sein (" präglaziale " Terrassen V-VII). Sie werden mit den 3 " Donau " Schottern von B. Eberl (1930) im Iller-Lech-System parallelisiert und gleich diesen als Äquivalente einer ältesten dreiteiligen Eiszeitengruppe (" Donau-Eiszeit ") aufgefasst.

Auch im Rheingebiet finden sich nach H. Breddin (1928) über der als gleichaltrig mit der Elstereiszeit angesehenen Hauptterrasse noch 5–6 höhere Terrassenstufen. Alle diese Höhenterrassen sind nach Breddin noch in die pliozäne Fastebene des Bergischen Landes eingetieft, müssen also jünger als diese sein. Nimmt man die von Soergel vertretene " periglaziäre " Entstehung aller dieser Terrassen als richtig an, so müsste man hier die Grenze Pliozän-Pleistozän nicht nur *weit* vor den Beginn der ersten norddeutschen Vereisung (Elster = Mindel II), sondern auch weit vor die alpine Günzvereisung legen.

In England gehört in den Zeitabschnitt vor der Elstereiszeit die Ablagerung des *Cromer Forest Bed* und ein Teil der *Crag-Serie*. Die ausgedehnte Vereisung, die über dem Arctic Freshwater Bed folgte und die den Cromer Till und die Norwich Brickearth ablagerte, war zweifellos die nordeuropäische Elster- oder Mindelvereisung. Wir wissen von keiner anderen nordischen Vereisung, die so weit reichte. Es besteht keine Möglichkeit, die Vereisung des Cromer Tills und der Norwich Brickearth etwa mit der alpinen Günzvereisung zu parallelisieren.

Die vor dem Cromer Forest Bed liegende Crag-Serie ist bekanntlich durch die allmähliche Zunahme nördlicher und die entsprechende Abnahme südlicher Molluskenformen gekennzeichnet. In dieser starken Zunahme nordischer Formen in der jüngeren Crag-Serie wird von zahlreichen Forschern der Einfluss einer nordischen Vereisung gesehen, einer Vereisung, die dann nur der Günzvereisung der Alpen entsprechen könnte. So legt P. Tesch (1930) die Grenze Pliozän-Pleistozän zwischen den Red Crag von Butley und den Norwich Crag, wohin sie auch James Geikie schon 1894 gelegt hatte. F. Zeuner (1937) glaubt zwei Invasionen arktischer Formen unterscheiden zu können: eine im Newer Red Crag und eine im Weybourne Crag. Er sieht darin zwei Günzphasen repräsentiert. Sollte diese Ansicht zutreffen, so müsste man die Grenze Pliozän-Pleistozän noch unter den Newer Red Crag legen.

Sieht man in dem Auftreten arktischer Formen im Weybourne Crag ein Anzeichen der Günzeiszeit, so muss man das über der Crag-Serie folgende Cromer Forest Bed als eine in die Günz-Mindel-Interglazialzeit fallende Ablagerung auffassen, wie dies heute die meisten Forscher tun. Die Fauna des Cromer Forest Bed—mit *Elephas meridionalis*, *E. antiquus*, *E. trogontherii*, *Rhinocerus etruscus*, *Equus stenonis*, *Hippopotamus amphibius*, *Trogontherium cuvieri* usw.—ist neuerdings nochmals kritisch

von F. Zeuner (1937) behandelt worden. Er betont die weitgehende Übereinstimmung mit der Hauptfauna von *Mosbach* und der von *Mauer*. Dem ist noch die Übereinstimmung mit der Fauna der oberen Sommeterrasse (45 m.) bei Abbeville und St. Acheul hinzuzufügen. Dies Vorkommen enthält u.a. auch *Elephas meridionalis*. Die obere Sommeterrasse ist ferner die primäre Lagerstätte des Abbevillien (früher Chelléen). Alle genannten vier Vorkommen sind mit grösster Wahrscheinlichkeit in die Günz-Mindel-Zwischeneiszeit zu stellen, wenn auch z.T. in verschiedene Abschnitte. Die stratigraphischen Gesichtspunkte, die für eine Einordnung des Cromer Forest Bed in die Günz-Mindel-Zwischeneiszeit sprechen, werden also bestätigt durch die Übereinstimmung der Faunen.

Es muss hier allerdings auf einige theoretische Schwierigkeiten hingewiesen werden, die sich bei diesen Auffassungen ergeben. Normalerweise haben wir während einer Eiszeit einen tiefgelegenen, während einer Zwischeneiszeit einen hochgelegenen Spiegel des Weltmeeres. In den Eiszeiten waren gewaltige Wassermengen in der Form riesiger Inlandeismassen festgelegt. Sie wurden den Ozeanen entzogen, so dass eine merkliche Spiegelsenkung eintreten musste. Diese ist für die letzte Eiszeit auf rund 100 m geschätzt worden. In früheren grösseren Eiszeiten ist wahrscheinlich mit einem noch erheblich grösseren Betrag zu rechnen. In den Zwischeneiszeiten floss das gesamte, vorher als Eis festgelegte Wasser dem Ozean wieder zu und erhöhte so seinen Spiegel von neuem.

In der angenommenen ersten Eiszeit, deren Spur in dem Auftreten arktischer Mollusken in der Crag-Serie erblickt wird, hatten wir sowohl in Ost-England wie in den Niederlanden einen verhältnismässig hohen Spiegel des Weltmeeres. In beiden Gebieten war damals Meer. Wir sollten aber einen tiefen Spiegelstand erwarten. In der darauf folgenden Zwischeneiszeit, in die das Cromer Forest Bed gehört, haben wir dagegen sowohl in England wie in den Niederlanden einen etwas tiefer liegenden Meeresspiegel. Wir sollten gerade das Umgekehrte erwarten. Hier bedarf es neuer eingehender Untersuchungen, um diese vorerst mit der Theorie garnicht übereinstimmenden Dinge zu klären.

Nun haben wir zweifellos in den Niederlanden, wie Lorié (1890) und Penck (1922) betont haben, seit dem Pliozän ein Senkungsgebiet vor uns. Dem stehen Hebungsgebiete im Süden—Flandern—und im Western—England—gegenüber. Die gleiche Schicht liegt in Kent mehr als 500 m. höher als in der Gegend von Utrecht. Eine verhältnismässig tiefe Lage der Niederlande in der Günz-Eiszeit liesse sich mit diesen Vorstellungen wohl in Einklang bringen, nicht aber eine relativ hohe Lage in der Günz-Mindel-Zwischeneiszeit. So liegt hier noch ein ungelöstes Problem vor. Man könnte aber auch daran denken, dass uns die wirklich tiefste Lage des Meeresspiegels während der Günzeiszeit garnicht erhalten geblieben ist, und dass die Zunahme der arktischen Mollusken im Weybourne Crag erst den Beginn der Eiszeit bei noch verhältnismässig hohem Meerespiegel anzeige, mit anderen Worten, dass der eigentliche Tiefstand des Meeresspiegels zwischen der Crag-Serie und dem Cromer Forest Bed gelegen hätte und für uns heute nicht mehr erkennbar wäre.

Kommen wir schliesslich ins *Mittelmeergebiet*, so ergibt sich dort für die Grenze Pliozän-Pleistozän Folgendes: Die Höchststände des Mittelmeergebietes lassen sich, wie dies F. Zeuner (1945) ausgeführt hat, in folgender Weise eingliedern:

Monastirian II	7— 8 m. ü.M.	Riss-Würm-Zwischeneiszeit.
Monastirian I	18—20 m. ü.M.	
Tyrrhenian	28—32 m. ü.M.	Mindel—Riss-Zwischeneiszeit.
Milazzian	55—60 m. ü.M.	Günz—Mindel-Zwischeneiszeit.

Das *Sicilian* mit einer Spiegelhöhe von etwa 80—100 m. über der jetzigen würde dann vielleicht in die Vorgünzzeit fallen. Faunistisch ist es durch eine Molluskenfauna mit " nordischen Gästen " und durch *Elephas antiquus* charakterisiert. Das ältere *Calabrian* mit *Elephas meridionalis* wird als gleichaltrig mit dem Villafranchian angesehen. Die untere Grenze des Pleistozäns ist hier fast stets zwischen Sicilian und Calabrian gezogen worden.

Zeigen sich nun aber im Calabrian—und in seinem terrestrischen Äquivalent, dem Villafranchian—Anzeichen von kühleren Zeiten, so können diese schwerlich mit der Günz-Eiszeit in Zusammenhang gebracht werden, sondern müssen vor dieser liegen. Es wäre zu prüfen, ob hier ein Äquivalent der Donau-Eiszeiten vorliegen könnte.

So zeigt ein Überblick über die Grenze Pliozän-Pleistozän in Europa, dass in vielen Gebieten eine klare Grenzziehung bisher nicht möglich ist. Im nordischen Vereisungsgebiet ist die Frage einer ältesten, der alpinen Günzvergletscherung entsprechenden Vereisung offen, ganz abgesehen von vielleicht noch älteren Kaltzeiten. Im periglaziären Bereich Mitteleuropas bedarf die Einordnung der zahlreichen " präglazialen " Terrassen noch der Aufhellung, während schliesslich im alpinen Gebiet die Frage von " Vorgünz "-Vereisungen (" Donau-Eiszeiten ") noch näher geprüft werden muss.

Gelingt es, die Grenze Pliozän-Pleistozän an einer Stelle einwandfrei festzulegen—es ist dafür ein marines Gebiet vorgeschlagen worden—so besteht die Möglichkeit, sie durch faunistische und floristische Vergleiche, in vielen Gebieten auch durch die Verfolgung eustatisch bedingter Strandlinien auf andere Gebiete zu übertragen.

Das Pleistozän, dessen Haupteigentümlichkeit, wie eingangs betont wurde, das weltenweite Auftreten von Kaltzeiten war, ist auch das Zeitalter der menschlichen Entwicklung. Die wesentliche Herausbildung des Menschen und die wesentliche Entwicklung seiner Kulturen ist im Pleistozän erfolgt. Es ist aus diesem Gesichtspunkt heraus vorgeschlagen worden—so besonders von Girmounsky (1932)—das Quartär als Formation des Menschen mit dem Namen *Anthropozoikum* zu belegen. Wenn diese Namengebung auch sachlich zutreffend erscheint, so liegt doch kein Grund vor, die in der ganzen Welt eingebürgerten Namen Quartär bezw. Pleistozän abzuschaffen. Der Gebrauch der Begriffe Quartär und Pleistozän ist zwar in den einzelnen Ländern etwas verschieden. In Amerika besteht eine Tendenz, unter dem Begriff Pleistozän das gesamte Quartär, einschliesslich des Holozäns, zu verstehen. In der Mehrzahl der Länder werden jedoch Pleistozän und Holozän als Unterabteilungen des Quartärs verstanden. Es wäre erwünscht, wenn diese Bezeichnungen, einschliesslich ihrer Unterteilung (Alt-, Mittel-, Jungpleistozän) und einschliesslich der Grenze Pleistozän—Holozän international festgelegt würden.

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THE PLIO-PLEISTOCENE BOUNDARY IN CHINA

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China

ABSTRACT

Five different types of sections dealing with the problems of the Plio-Pleistocene boundary in China are discussed first. Further discussions are made from the point of view of sedimentation, geological structure, physiography, glacial geology and fossil remains. On the whole the boundary line between the Pliocene and the Pleistocene seems best placed between the Nihowan and the Choukoutien, at least in the Huangho region. But westwards as well as southwards this view raises some difficulties.

A simplified list of mammalian remains is given to show first appearances and last survivors in the three main faunas which are relevant to this problem—the " Middle Pliocene," the Nihowan and the Choukoutien faunas. Views on the two main possibilities (placing the boundary between " Middle Pliocene " and Nihowan, or between Nihowan and Choukoutien) are discussed.

A table of Pliocene and Pleistocene subdivisions, according to the nature of deposits—fissure, gravel, lacustrine and loamy facies—is given, with the two possible solutions to the boundary problem; one placing it on the top of Nihowan and the other at the base of the Nihowan. The former is the one accepted by the Caenozoic Research Laboratory.

INTRODUCTION

OPINIONS concerning the Plio-Pleistocene boundary are divergent in almost every country. One puts more weight on the evidences of palaeontology and another on those of tectonics. There are still others who consider that climate and physiography are equally important factors to consider in drawing the line between two major geological formations. Sometimes these factors are complementary, sometimes they are rather contradictory.

As the Caenozoic deposits are generally confined in separated basins, and yet lithologically quite similar to each other, it is obvious that the exact identification of their age is in many cases difficult without palaeontological data.

During the past thirty years of field and laboratory researches by geologists and palaeontologists on the late Caenozoic stratigraphy and its related problems in China, many facts concerning the separation of the Pliocene and Pleistocene have been accumulated. In general the practice adopted by the Caenozoic Research Laboratory has been to draw the line between the Nihowanian* and the Choukoutienian. This is however objected to by H. de Terra who puts the line below the Nihowan.

The aim of this paper is to summarize the most important observations regarding this problem. Some leading sections and data collected from various parts of China are given first. Then discussions from various points of view are summarized, with a statement of what the author considers to be the most satisfactory conclusion without, however, attempting to give a final decision.

DESCRIPTION OF SECTIONS

The sections observed in different parts of China, bearing on the problem of the Plio-Pleistocene boundary, may be classified into five groups. It would suffice to give one of each type as an example for discussion. The five categories of section are as follows: *A.*—Supposed uppermost Tertiary deposits which are tilted while supposed basal Quaternary deposits are not affected by warping or disturbance; *B.*—Both are tilted; *C.*—Supposed Pleistocene deposits of which the precise age is uncertain, or their lower boundary is not clear, but which are lying on much older rocks; *D.*—Supposed uppermost

* In the present paper I purposely avoid the term " Villafranchian," which is equivalent to Nihowanian, but in the European standard.

Tertiary and supposed lowermost Pleistocene deposits, neither of which is tilted, but as both lack fossils their age can be given only by indirect comparison; *E.*—Cave deposits.

Category A.—Sections of this type are commonly found throughout North China, from Charhar to Kansu. The two sections given are in Sankanho and the Yueshê basin. The tilted dominantly lacustrine Pliocene beds are overlain with angular unconformity by the Pleistocene talus deposits. Similar sections are found in other parts of Shansi (Taiku) and Central Kansu (Young and Bien, 1939).

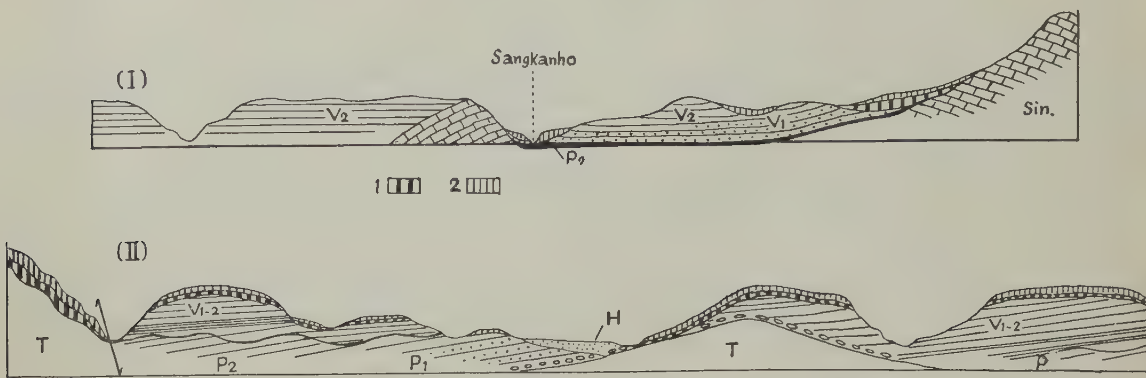

FIG. 1.—*Two comprehensive sections in the late Caenozoic deposits of North China (slightly diagrammatic and not on the same scale).*

(I) Nihowan Basin (south-east Charhar); length of the section, 12 km. (II) Yushê Basin (south-east Shansi); length of the section 8 km. *Sin.*—Sinian quartzite and sandstone. *T*—Triassic sandstone. *P*—Early Pliocene (*P*.1—Pontian; *P*.2—" Middle " Pliocene White Beds). *V*—Villafranchian (*V*1.—Lower sands; *V*.2—Upper White Beds). 1—Early Pleistocene Red Clays (*tingi* beds). 2—Late Pleistocene (Loess). *H*—post-Pleistocene sands. Observe the sharp disconformity (or even unconformity) between the dominantly lacustrine Pliocene beds and the Pleistocene slope-deposits. (*After Teilhard and Young*).

Category B.—Westwards from Central Kansu along the northern foot of Chilien-shan the late Caenozoic deposits are strongly tilted. At Wenshushan south of Suchow the Yumen gravels are tilted and the upper Kansu formation is even overthrust upon the Yumen gravels. Unfortunately there is no palaeontological proof of the precise age of either the Upper Kansu formation or of the lower part of the Yumen gravels. But westwards along both sides of Tienshan, especially clearly visible in the Kucha region, a similar condition is found (Huang and others, 1947). There, the so-called *A* gravels which are tilted, unconformably overlie the Upper Kucha formation with fossil plants of " Upper Pliocene " age. Therefore it is possible that the Yumen gravels are most likely of Lower Pleistocene age. According to Huang, however, the Yumen gravels themselves are separated by an unconformity, so that the question arises as to which one we should consider as the actual boundary between Pliocene and Pleistocene. (See Fig. 2).

Category C.—In southern China sections are commonly found in which the deposits lack satisfactory fossil evidence, but indirectly appear comparable with early Pleistocene formations; or the supposed early Pleistocene deposits are lying upon much older rocks, so that the lower limit of the Pleistocene is not clear. To mention an example of the latter case, there is a section north from Anking where Lower Pleistocene beds lie directly on the Pukou Series of presumably Early Tertiary age. An example of the former case will be mentioned under Category D. This kind of contact is commonly known in most parts of South China where Pliocene beds are wanting, or the exact age of the beds underlying the Pleistocene is unknown. (See Fig. 3).

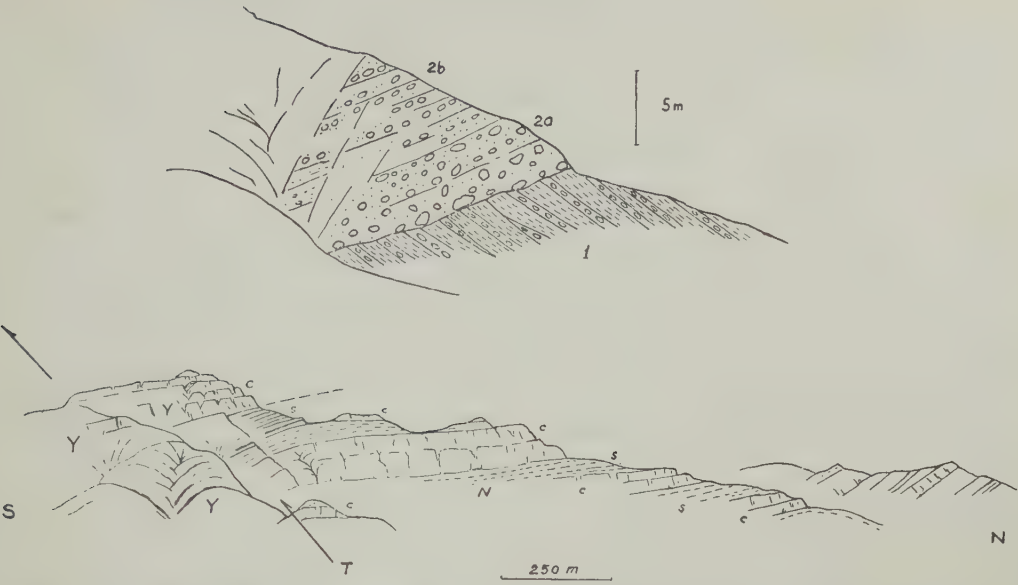

FIG. 2.—(Upper figure): *Unconformity between Kotongkou Beds and Yumen gravel, seen* $1\frac{1}{2}$ *km. north-east of Hoshihshan, near Shihyouho, Kansu.*

1—Loose conglomerate and sandstone forming uppermost portion of red beds bearing petroleum (Suleiho Series of C.C. Sun); this may be correlated with the Upper Kusha formation. 2*a*—Coarse gravel, almost unstratified with boulders reaching occasionally 2 m. across. 2*b*—Similar gravels but distinctly stratified and less coarse. The unconformity shown in this section might be taken to represent the Plio-Pleistocene boundary. The basal boulders may be glacial in origin, representing relics of a ground moraine.

(Lower figure): *South limb of the Wenshushan anticline.*

Y—Yumen gravel; *N*—Niukotao stage of Suleiho Series (probably of Upper Kusha formation); *c*—conglomerate; *s*—sandstone or sandy loam beds; *T*—Thrust contact. Note the older Niukotao beds in thrust-contact with the younger Yumen gravel. (*Both sections are from Dr. T. K. Huang's unpublished notes,* 1941. *The author is deeply indebted for his courtesy.*)

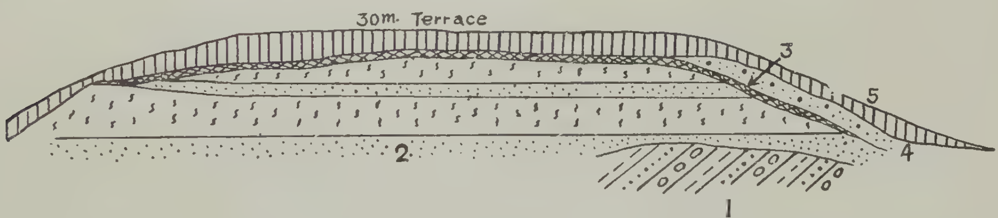

FIG. 3.—*Section taken N. of Anking.*

1—Pukou Series; 2—Yuehatai gravel and vermiculated clay; 3—Iron crust; 4—Red clay (redeposited from the Yuehuatai Series); 5—Hsiasu loam. (*After Teilhard and Young*).

Category D.—Under this head we shall group some sections in which either the lower unit is not tilted (or only weakly disturbed and nearly horizontal) or both the upper and lower units are horizontal. In such cases the contact at least looks conformable, and the separation is very difficult, if no fossils are known in the beds. Sometimes we can get clues from indirect evidence. The section taken from the vicinity of Choukoutien is typical of this type, and explains both the present case and the situation stated above under C. In this section the upper gravels are indirectly correlated as equivalent to the gravel pocket (Locality 12) of Nihowan age, and the red clays above to the other locality (Locality 13) which yields typical Lower Pleistocene fossils. Therefore the boundary should be between the gravels and the red clays; which is not very convincing when no other evidence is available. (See Fig. 4).

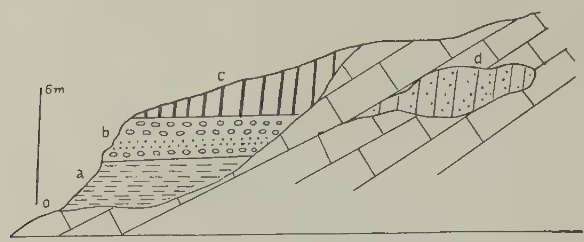

FIG. 4.—*Section through the hill slope of Choukoutien.*

a—Yellow sand and clay; *b*—Sand and gravel; *c*—Red clay; *d*—Pocket filled by red sand and clay and pebbles. (*After Teilhard and Pei.*)

Category E.—In considering the problem of the Plio-Pleistocene boundary, cave and fissure deposits must also be taken into account. In Choukoutien, the subaerial deposits of Localities 9 and 13 etc., are definitely Lower Pleistocene in age, as established by their rich mammalian faunas. The water-laid deposits represented at Locality 12, on the contrary, are of Nihowan or even older age. Therefore at least in Choukoutien, the Pliocene and Pleistocene boundary seems to be represented by some climatic change. In a much higher region of the Western Hills at Huiyu the " Upper Pliocene " fissure deposits are represented by subaerial facies (Locality 18). This seems to suggest that their facies were determined by local conditions rather than by universal change. The section given for Choukoutien is schematic, designed to show the entire sequence in the Choukoutien region. It seems to be very obvious that the history from Upper Miocene to Upper Pliocene is represented by the deposits numbered 1–3, which indicate a much older cave-fissure system antedating the Quaternary. The cap-travertine, now on the top of the hill, was actually the bottom of a destroyed cave. The second generation caves (4 and later) are of Quaternary date. So the hypothetical boundary line is quite clear. (See Fig. 5).

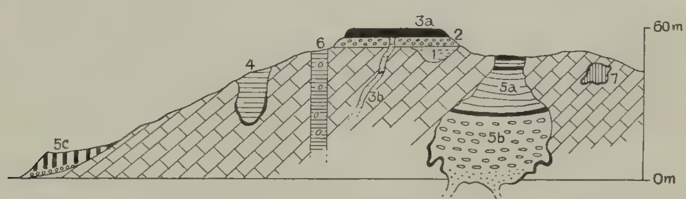

FIG. 5.—*Sequence of the fissure-deposits in Choukoutien.*

1—Yellow sands (fish pocket), Miocene (?); 2—Upper Gravel, Pontian (?); *3a*—Cap-travertine, and *3b*—Locality 12, " Middle " Pliocene; 4—Red Clays with *Siphneus epitingi*, *Euryceros flabellatus*, of Locality 13, " Lower " Early Pleistocene; *5a*—Upper Zone and *5b*—Lower Zone of *Sinanthropus* beds, Locality 1, " Middle " Early Pleistocene; 6—Locality 3 " Late " Early Pleistocene; 7—Upper Cave, Late Pleistocene; *5c*—terrace probably corresponding to the *Sinanthropus* beds. *b*—the Cap-travertine (3a is regarded here as the stalagmitic floor of a former cave, the " roots " of which are represented by the *Cynocephalus*-gravels of Locality 12 (3*b*)).

(Note the presumed or hypothetical line between the Pliocene and Pleistocene separates the dominantly lacustrine deposits of 1—3 from the dominantly clayey deposits, 4 onwards). (*After Teilhard*).

In South China the oldest known cave is surely represented by the deposits containing *Stegodon-Ailuropus* of Lower Pleistocene age. Yet, it is quite possible that conditions similar to those in Choukoutien may have occurred, because at least in Wanhsien, traces of *Mastodon* were recorded, suggesting a much older cave filling.

THE BOUNDARY BETWEEN THE PLIOCENE AND PLEISTOCENE FROM THE VIEWPOINT OF STRATIGRAPHY

From the data given above we must admit that the boundary line is rarely known with certainty. Even in the case of sections in Category A, the age of the tilted part is sometimes difficult to determine,

e.g. in Kansu, Kwangsi (the Yungning Series) and many other parts. The same difficulty applies also in the case of sections in Category B, *e.g.* it is uncertain whether the Yumen gravels actually all belong to the Lower Pleistocene or form part of a complex. There is no fossil evidence. As for the other obscure cases, where no evidence of the boundary is available at an actual contact, it is obvious that one can only reach some conclusion by inference. Nevertheless, a tentative conclusion may be summarized below.

Formerly the red loams with *Siphneus tingi* were considered as the slope facies of the Nihowan deposits. Later researches have shown that these loams lie directly on the Nihowan beds, and the much smaller so-called *Siphneus tingi* from the Nihowan beds may not be the true *S. tingi* (perhaps *S. chaoyatseni*?). If this new interpretation is correct, as it would seem to be, the boundary between the Pliocene and the Pleistocene is quite evident. The uppermost Pliocene is predominantly in lacustrine and fluviatile facies, while the Lower Pleistocene is largely represented by loamy facies. This explanation agrees well with the cave deposits of Choukoutien, where all the Tertiary fissures contain water-laid deposits, and the Pleistocene ones subaerial or brecciated cave deposits.

Whether such views hold true for South China or not is still an open question. It is evident that the situation there is quite different from what we know in North China, if the red vermiculated clay represents the uppermost Pliocene. On the contrary, if the red vermiculated clay is Lower Pleistocene, conditions would be quite similar in both North and South China. Nevertheless, it must be mentioned that the southern " red clay " is also represented in many cases by gravel (Yuhuatai, Peishaching and the tin-bearing gravels etc.), and cannot be regarded as entirely a slope facies. Chiefly owing to the lack of direct contact between the lower, or Pliocene beds, and the lower limit of the upper beds, an undisputed line is difficult to draw. Yet as a stratigraphical unit the dominantly lacustrine Nihowan beds seem better considered as uppermost Pliocene rather than as Lower Pleistocene.

THE PLIO-PLEISTOCENE BOUNDARY FROM THE VIEWPOINT OF GEOLOGICAL STRUCTURE

The above mentioned conclusion is certainly supported by the structural evidence. In all places where the Pliocene strata have been subjected to later warping or tilting, the Pleistocene deposits lie on a peneplaned surface, which marks the most distinct separation between the two formations. This appears locally the best basis for a separation of the Pleistocene from the Pliocene, regardless of the stratigraphical and palaeontological grounds. In this region the boundary line between the Tertiary and the Quaternary is more clearly indicated than that, in many cases, between the Proterozoic and the Palaeozoic, or the Palaeozoic and the Mesozoic, or the Mesozoic and the Caenozoic, for only the latter is marked by a clear angular contact.

But this criterion does not serve in the western part of China, where the Yumen gravels and their equivalents are strongly affected by disturbance. Furthermore, the Boulder Conglomerates in North India are similarly disturbed, yet their age is most likely the same as the Early Pleistocene fan deposits of China. However, it is admitted that structure alone cannot be used as a basis for separation. It is therefore only for the sake of convenience that it is practical to draw the line between the Pliocene and the Pleistocene in North China on the basis of structural evidence, and cannot be applied in other parts where the late Caenozoic beds are mostly tilted.

PLIO-PLEISTOCENE BOUNDARY FROM THE VIEWPOINT OF PHYSIOGRAPHY

What we consider as the study of physiography is not limited merely to observation of morphology, say the elevation of different terraces, and so on, upon which physiographical stages are based; the evidence of fossiliferous deposits and of sedimentary cycles is also taken into consideration when establishing the succession of erosional and depositional cycles.

As a result of some thirty years of research on various lines a fairly satisfactory picture can be drawn of the development of the land-surfaces of China since the close of Miocene times. This has been briefly summarized by Teilhard in a graphical form (1941, p. 40). Since the end of the Miocene period,

there have been seven more or less clearly recognized (*a*) erosional and (*b*) depositional stages, viz.: 1.* (*a*) Tanghsien, (*b*) Paothe; 2. (*a*) Unnamed stage, (*b*) Yushe (or Chinglo); 3.* (*a*) Fenho, (*b*) Nihowan; 4.* (*a*) Huangshui, (*b*) Choukoutien; 5.* (*a*) Chingshui, (*b*) Malan; 6. (*a*, *b*) Pair of unnamed stages; 7.* (*a*) Panchiao, (*b*) Recent.

Among these only two erosional stages appear to be possible candidates for the line of Plio-Pleistocene boundary, the Fenho stage and the Huangshui stage. The former was long accepted as responsible for the most intensive gorge-cutting in North China. But our observations made in Kansu have shown that at least in West China gorge-cutting was more prominant in the Huangshui stage. It is therefore more convenient from the physiographical point of view to choose the Huangshui as the beginning of the Quaternary.

Of course the evidence of physiography alone is not sufficient for drawing a definite line between the Pliocene and the Pleistocene, but in this case it agrees remarkably well with the other facts already mentioned above.

THE PLIO-PLEISTOCENE BOUNDARY FROM THE VIEWPOINT OF GLACIOLOGY

In the Himalayan region the first glaciation occurred in the Fenho erosional stage, according to Teilhard de Chardin (1941). That is to say the first glaciation began before the Boulder Conglomerate stage of India and the Nihowan time of China, although partly contemporary with them. This would agree with placing the Plio-Pleistocene Boundary at this very period, for Tertiary glaciation, so far at any rate, is not positively recognized anywhere in the world.

It is interesting to note that in spite of different opinions concerning the late Caenozoic formations (notably at Lushan), between J. S. Lee and Teilhard and others, we found at least one point of agreement, that is in putting the first glaciation before the deposition of the dark red series.

In the memoir by Lee (1947) on Quaternary Glaciations in the Lushan Area, Central China, there are three periods of glaciation positively recognized, viz.:—

III. *Lushan glaciation*, with reddish loams and boulder clays; limited to the higher altitudes of the mountain.

II. *Taku glaciation*, with brick-red boulder clays and clays, loosely consolidated and poorly lateritized.

I. *Poyang glaciation*, with dark red boulder clays and red clays, cemented and strongly lateritized.

The materials considered as the products of the Poyang glaciation are doubtless the same as what Teilhard called the " oldest boulder fan of Kuling near Kiukiang " (Villafranchian according to him); and those of the second Taku glaciation are the same as the Yuhuatai gravels, interpreted by Teilhard as equivalent to the red clays of North China (Choukoutien, Loc. 13, etc.). Both authors agree on the time of glaciation as far as the stratigraphical units are concerned, but differ in opinion as to geological dating. Lee put the first glaciation at the base of the Quaternary, while Teilhard shifted it to the upper part of the Pliocene. As stated above, the latter correlation seems rather unusual in view of the position of the first glaciation in other parts of the world. There are many Caenozoic geologists, including Teilhard, who are still not quite ready to accept the alleged glaciations in the lower Yangtze Valley without reservation. It is out of place here to discuss this problem in detail but I wish only to point out on this occasion that if the glacial sequences are established as set forth by Lee, most of the well-known faunas found in North China, as well as those of the fissure deposits and cave fillings with fossils in South China, have to be considered as belonging to the interglacial periods† and cannot be so

* These are the most obvious erosional and depositional stages, with well recognized fauna in the depositional facies.

† As is well known, most of the elements of the faunas indicate a warm climate, with only very few exceptions, presumably survivors from a preceding cold phase.

simply related as in the schematic grouping given by Teilhard (1941, pp. 44–45). If so, it is very hard to explain why in South China there is no single place with interglacial deposits containing fossils comparable with what we know from North China apart from the cave facies.

As far as the glacial problem is concerned, the base of the Pleistocene would be best placed before the dark red series near Kiukiang, which is rather contradictory to the conclusions drawn from the other points of view.

THE PLIO-PLEISTOCENE BOUNDARY FROM THE VIEWPOINT OF PALAEONTOLOGY

Among fossils, the mammalia are the most significant group in regard to the present problem. Since fossils plants are very poorly known in China and the invertebrates from the different beds show few conspicuous differences, or have not yet been well studied (the freshwater shells for instance), we are bound to rely chiefly on fossil mammalia for age separation. Most of the better known mammalian faunas of the Plio-Pleistocene time are restricted to North China. The chief localities are:—

North China.—The Nihowan, Charhar; Upper Yushe beds of Yushe, South-east Shansi; Chinglo, North-west Shansi; Choukoutien, Localities 12, 13, 9, 1, 15, 18, 6.

South China.—Various cave and fissure deposits of Szechuan (notably Wanhsien), Kwangsi, Chekiang, Kiangsi, Kiangsu.

For the sake of convenience the Early Pliocene (Pontian) and Late Pleistocene faunas are omitted from those enumerated. On p. 122 is a list, based chiefly on the localities already named, showing the stratigraphical distribution of the fossil mammals. This list has been copied from one prepared by Teilhard, but two simplifications have been made in order to give a more explicit picture of mammal life during those stages which are critical in considering the boundary in question. First, I have omitted the Pontian and late Pleistocene columns from Teilhard's list, since neither has a direct connection with the problems under discussion. Second, forms which are common in all three levels such as *Canis* and *Meles* are omitted. By doing this, we obtain a clear, more or less statistical, picture of the faunal changes, with the positions of last survivors, and of forms making their first appearance. Immigrant forms are marked with* and the true Asiatic forms with†. The larger groups such as families and sub-families are given in capitals.

From the list (on p. 122) the following points may be discussed. First statistically, there are fifty-nine forms or groups, among which nine became extinct during or at the end of the " Middle " Pliocene, fourteen during or at the end of Nihowan time. As for the incoming forms, twenty appeared at the beginning of the Nihowan stage and sixteen in the Choukoutien stage. It is therefore obvious that the Nihowan fauna is more closely related to the Choukoutien fauna than to that of the " Middle " Pliocene.

Second, it is generally recognized that the extinction of forms has less value in separating geological ages than the incoming of new forms. More new forms appeared at the beginning of Nihowan times than at the commencement of the Choukoutien period. This would point to the same conclusion as the first one.

Third, analysing single forms, it is obvious that nearly all the archaic types so characteristic in the Lower and " Middle " Pliocene, such as *Hyaenactos*, *Ictitherium*, *Chilotherium*, Giraffidae, Mastodontidae, etc., were extinct before the dawn of the Nihowan age. The Nihowan fauna is characterized by the first appearance of many modernized forms, new invaders from other continents, but shows as yet little influence of a southern fauna.

So far the points are in favour of considering the Nihowan as the beginning of the Pleistocene. But if we turn to the other possibility, it seems that to consider the Choukoutien as the base of Quaternary is equally sound, or even more justifiable.

First, we must not forget that what we called the Nihowan fauna is only considered as the uppermost part of the Pliocene. The duration of the Upper Pliocene is at least four million years (Simpson, 1947), which is almost four times longer than the duration of the Pleistocene. Therefore it is rather

DISTRIBUTION OF FOSSIL MAMMALIA IN "MIDDLE PLIOCENE," NIHOWAN AND CHOUKOUTIEN STAGES

	"Middle Pliocene"	Nihowan	Choukoutien (Loc. 1 etc.)
CARNIVORA			
Cuon		——	——
Ursus†		——	——
Hyaenarctos	——		
PROMELIDAE	——		
Arctonyx			- - - -
Mustela		——	——
Gulo			——
Lutra		——	——
Ictitherium	——		
Hyaena licenti		——	
Hyaena sinensis			——
Hyaena ultima			- - - -
RODENTIA			
Ochotonoides†		——	——
Hypolagus†	——	——	
Lepus†			——
Prosiphneus†	——	——	
Siphneus armandi†		——	——
S. arvicolinus†		——	——
S. fontanieri†		——	——
S. tingi†		——	——
Rhizomys†	——	——	- - - -
Hystrix†		——	——
PERISSODACTYLA			
Postschizotherium	——	——	
Chilotherium	——		
Rhinoceros sinensis			——
Rh. schleiermacheri	——		
Rh. mercki†		——	——
Rh. tichorhinus†		——	——
Elasmotherium	——	——	
Hipparion	——	——	
Proboscidipparion		——	
*Equus sanmeniensis**		——	——
ARTIODACTYLA			
*Camelus**		——	——
GIRAFFIDAE	——		
CERVULINAE*	——	——	
Hydropotes			——
*Elaphurus**		—— ? ——	
Axis rusa		—— ? ——	
Dama		——	
Euryceros			——
Pseudoaxis			——
Antilospira	——	——	
Spirocerus		——	——
Bubalus			——
*Bison**		——	—— ? ——
Boopsis			—— ? ——
Ovis		——	——
Bibos			- - - -
PROBOSCIDIA			
MASTODONTIDAE	——		
STEGODONTIDAE	——	- - - -	- - - -
Elephas cf. *planifrons*†	——		
E. cf. *meridionalis*†		——	
E. namadicus†		——	——
PRIMATES			
Macacus			——
Cynocephalus	——	——	
Hylobates			- - - -
Orang			- - - -
Gigantopithecus			- - - -
Sinanthropus			——

natural that the Nihowan fauna should appear to be more affiliated to the Choukoutien fauna than to the genuine, " Middle " Pliocene fauna.

Secondly, speaking of the mammalian elements themselves, the Choukoutien fauna is marked by several new fully modernized forms such as Leporidae, modern deer, sheep, water-buffalo, and bison in addition to the few vestiges of some older forms such as *Hyaena* and *Rhinoceros*. Still more important is the appearance of Man in this stage.

Thirdly, the Lower Pleistocene fauna of China is especially distinguished by the sudden change of direction of the migration of the faunas. Instead of mainly east-westwards direction in the preceding periods, the Choukoutien time is remarkably characterized by the invasion of southern forms, indicated by broken lines in the list. *Sinanthropus* is one of the leading forms. So far no human remains have been found before the Choukoutien stage in China, which agrees well with the general assumption that the Quaternary is the age of Man. This however is not to be regarded as a serious consideration, for human remains are likely to be found some day also in late Pliocene strata.

To sum up, on the basis of the above considerations, it seems justifiable to take the beginning of the Choukoutien stage as the Plio-Pleistocene Boundary. Palaeontologically we may say that the Nihowan and the Choukoutien faunas are as closely affiliated as any other two Caenozoic faunas in China, but it would do no harm to consider the former as the top of the Pliocene, and the latter as the base of the Pleistocene. The faunastic distinctions between the two are sufficient to make palaeontology a good criterion for separating Pleistocene from Pliocene.

CONCLUSIONS

1. If one considers the relatively well known area of middle and lower Huangho region it is both *practical* and *natural* to consider the boundary line between the Pliocene and the Pleistocene as falling between the Nihowan and the Choukoutien stages. This may be demonstrated best in the following way:—

<table>
<tr><th></th><th>Upper Pliocene</th><th>Lower Pleistocene</th></tr>
<tr><td>Sediments</td><td>Lacustrine deposits dominant</td><td>Sub-aerial and slope deposits dominant</td></tr>
<tr><td>Structure</td><td>Beds tilted</td><td>No warping or tilting</td></tr>
<tr><td>Physiography</td><td colspan="2">Huangshui erosion, gorge-cutting.</td></tr>
<tr><td>Fauna</td><td>Aberrant deer and archaic Perissodactyla (subsequently extinct).</td><td>Beginning of water-buffalo, flourishing of Euryceros deer and rising of Man</td></tr>
</table>

2. But the first two criteria fail to apply in the western part of China, where the beds supposed to be Lower Pleistocene are strongly tilted and largely detrital.

3. The old red vermiculated gravels and clays of supposed glacial origin in South China have to be considered as Lower Pleistocene instead of Upper Pliocene.

4. Both in South China and in West China palaeontological data are insufficient to enable precise correlation to be made with what we know in North China.

5. Until new facts are forthcoming it seems better and natural to use the succession in North China as the standard when considering the question of the Plio-Pleistocene boundary line.

6. The sequences of the Pliocene and Pleistocene deposits, grouped into four main items according to the nature of the sediments, are given in the accompanying Table. The author's first choice of Plio-Pleistocene boundary is given in a heavy solid line, while the second choice is shown by a broken line.

TABLE

		CAVE AND FISSURE DEPOSITS		GRAVEL AND PIEDMONT FACIES		LACUSTRINE FACIES		SLOPE OR LOAMY FACIES	
		North	South	North	South	North	South	North	South
		Chiefly at Choutien							
HOLOCENE								Black Earth	
PLEISTOCENE	Late	Upper Cave	*Paludina*- and bone-beds; Neolithic caves of Kwangsi	Basal loessic gravels	Peishaching gravels	Sarra osso-gol beds		Secondary loess Loess	Hsiahsu loams
	Early	Late Early Pleistocene (loc. 3) *Sinanthropus* beds (loc. 1) *Euryceros flabellatus* beds (loc. 13)	*Stegodon-Ailuropus* beds (Wanhsien) ?*Gigantopithecus*-bearing cave	Younger Gobi gravels Yumen gravels* Basal reddish clays, gravels Kucha gravels	Yuhuatai gravels			Yuling series *S. tingi*-bearing red clay	Light lateritized red clay
PLIOCENE	Upper				Dark red cemented gravels	Nihowan beds	Yuanmo beds Hsiawanpu beds		Highly lateritized red clays
			Mastodon-bearing cave of Wanhsien						
	Middle	*Cynocephalus* beds (upper travertine and locality 12)		Intermediate Gobi gravels		Ertemte beds Yueshe beds	Yungning beds	Chinglo beds	
	Lower	Upper Gravels		High gravels on the top of the foot hills of W. Hills		Lutzekou Series		Pontian red clays	
MIOCENE		Fish-bearing beds		Oldest Gobi gravels			?Lower Yungning Series		

* The wavy underline shows the tilted series.

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THE LOWER BOUNDARY OF THE PLEISTOCENE

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ABSTRACT

Though the Pleistocene is no more than an appendix of the Pliocene, it may be advisable to retain it as a separate period for practical reasons, mainly because its chronology is on the whole one of *denudation*, whilst that of the earlier periods is mainly one of *deposition*. Its delimitation from the Pliocene is inevitably arbitrary. That based on the Günz glaciation of the Alps works only in glaciated areas, whilst boundary lines based on the appearance of certain mammalian genera can be used only where fossiliferous deposits occur. Moreover, since time was required for these genera to evolve and to extend their area of distribution, they cannot afford a boundary line sufficiently precise for the purpose of definition. It appears that physiographical methods will become increasingly applicable, especially if combined with faunal evidence. On the European continent, a new cycle of erosion began approximately at the time of the Günz glaciation, and when *Elephas* and other mainly Pleistocene genera appeared. Similarly, after oscillations around the 100 metre-mark during the Sicilian, the sea-level dropped to its present height in the course of the Pleistocene. The beginning of this drop would afford a good boundary line, since on the continents it initiated the new erosional cycle, evidence for which can be found in regions as far apart as Western Europe and eastern Asia.

THE conception of the Pleistocene as a geological period has developed along three almost independent lines. The first is that introduced by Charles Lyell, who defined the Pleistocene by the proportion of extinct to living species in faunas of marine mollusca. Since then, the term Pleistocene has been most consistently used in connection with marine faunas, especially in the Mediterranean area.

On the other hand, the period of time occupied by this marine Pleistocene coincides, broadly speaking, with the Ice-age. The phenomena of glaciation were studied most intensively in Continental Europe, where in the early days of geology the deposits in question were considered as the result of a great flood. Hence the term " Diluvium " which is used in the literature on the glaciations of central and eastern Europe. Following the great work of Penck and Brückner on the glaciations of the Alps, the Diluvium was universally accepted as beginning with the first large glaciation of the Alps, *i.e.*, Günz. Much physiographical and glacio-geological work has been done in Europe on the basis of this conception which, however, was in no way tied up with Lyell's marine definition. Yet in a vague manner, the terms Pleistocene and Diluvium were quite generally accepted as synonymous.

The third approach is that by way of mammalian palaeontology. As the descriptions of mammalian faunas increased in number it was found that a marked change occurred rather early in the period considered. It was later found to be connected with the strong climatic influence of the second large glaciation, namely Mindel. From that time onwards, the mammalian fauna is essentially modern, though comprising extinct types like mammoth, woolly rhinoceros, etc. This was called the typical, Pleistocene, or Diluvial, land fauna, as the case may be. But prior to the Mindel glaciation it was found that a varying number of species survived from what was commonly regarded as Pliocene times into the First Interglacial. It was also noticed that a number of the so-called typically Pleistocene types, like *Bos*, *Elephas*, true horse, had made their appearance before the Mindel Glaciation, and that the pre-Mindel faunal assemblages could be classified into early and late ones according to the number of " modern " species contained. Those who were impressed by the " Pliocene survival " components in these faunas, relegated the entire sequence to the Pliocene, whilst other workers who considered the appearance of new types as more significant than the date of extinction of survivors, considered

the inclusion of the later part of this complex of pre-Mindel faunas in the Pleistocene. This view is by now almost universally accepted, so that all faunas of the Cromer Forest Bed type, although they contain " Pliocene survivals," are regarded as early Pleistocene. This, however, has created a difficulty by introducing a split in the sequence of the pre-Mindelian faunas. These had often been collectively called Villafranchian. If the Günz Glaciation was accepted as the first Pleistocene event, then part of this " Villafranchian " would be Pleistocene, part Pliocene. If the entire " Villafranchian " was included in the Pleistocene, a pre-Günzian period would have to be added to the Pleistocene. The first alternative is favoured by Continental workers familiar with the Alpine and periglacial areas, and they restrict the term " Villafranchian " to faunas of the Val d'Arno type, leaving Cromer, Mosbach, Mauer, etc. in the Pleistocene. (This Villafranchian of the Val d'Arno type is here called Villafranchian *sensu stricto*). The second alternative has been accepted by workers whose palaeontological material cannot be subdivided sufficiently on stratigraphical evidence, *i.e.*, mainly in areas like Africa and Asia, removed from Continental Europe with its detailed divisions. In recent years, however, evidence has been found which may be used to support the second alternative. Research by Eberl in the Alps and by Soergel in central Europe revealed that cold phases occurred in pre-Günzian times, well-known now as the Donau stages, a name given to them by Eberl. But these appear to have been weaker than the Günz glaciation, and for this reason they have left traces only in some areas. Furthermore it was found that the Villafranchian was contemporary with the Sicilian and the Calabrian phases of the Mediterranean sea, formations which were generally regarded as Upper Pliocene. By now it has become imperative to make an attempt to disentangle this nest of hazy definitions, and it is hoped that the discussion at this meeting of the Congress of the problems involved will bring us a step nearer to solution.

It is evident that it will be necessary to bring the physiographic or glacio-geological interpretation into line with the palaeontological ones, *i.e.*, both that based on the marine, and on the terrestrial faunas. There have so far been very few links, partly because deposits which yield information about glaciations are not normally fossiliferous.

There is another difficulty, namely, that the succession of climatic phases of the Pleistocene (using the term in a vague sense) is based largely on phenomena of denudation, whilst the marine succession is based on phenomena of deposition. Yet both have a common meeting-ground in the study of physiographic cycles and in particular of raised beaches. The Eustatic Theory of glaciation, so ably developed by R. A. Daly, identifies high sea-levels with interglacials, and low sea-levels with glaciations. Some of the phases of high sea-level can be identified with the Calabrian, Sicilian, and so on, and the intervals between them can in part be identified with certain glaciations. There is here an important link which has not yet been exploited to the full.

Furthermore, the intensity of denudation has varied in the late Pliocene and the Pleistocene. There is evidence that a fresh cycle of erosion began somewhere about the Günz glaciation, possibly a little earlier. This sort of evidence is of great value as it can be recognized in many areas where fossils are scarce. It, too, is worthy of much closer attention than has been accorded to it hitherto. It has been used, among others, by Teilhard de Chardin, in defining the beginning of the Pleistocene in China. In that country the new erosional cycle began after the Villafranchian (*sensu stricto*). Since erosional cycles depend on the relative position of the sea-level, this physiographic approach is intimately connected with that by means of raised beaches.

The significance of raised beaches for the delimitation of the Pleistocene lies in their wide distribution. In tectonically stable areas, eustatic oscillations leave traces of beaches at constant heights. Though many localities, particularly on the coasts of the south-western Mediterranean, have proved not to fulfil this requirement of tectonic stability, many others remain on the Atlantic coasts of Europe, in the Mediterranean, and even farther afield, which show that certain heights of raised beaches above the present sea-level are encountered again and again. In the mouths of rivers they have been linked with deposits inland by stratigraphical and geomorphological methods, and the following succession

of reconstructed mean sea-levels appears to apply in Southern England, the Channel Islands, North France, the Italo-French Riviera, and north-western Italy.

Calabrian level	c. 200 m.	above	present	sea-level
Highest Sicilian level	103 m.	,,	,,	,,
Milazzian level	56 m.	,,	,,	,,
Tyrrhenian level	32 m.	,,	,,	,,
Main Monastirian level	18 m.	,,	,,	,,
Late Monastirian level	7.5 m.	,,	,,	,,
Interstadial level	c. 1 m.	,,	,,	,,

It should be noted that these are *altimetric* definitions, and that they tally with the faunal divisions as follows: The Calabrian has a well-known fauna of its own, the Sicilian and Milazzian *levels* contain Sicilian fauna, the Tyrrhenian and Monastirian *levels* contain Tyrrhenian fauna.

It is evident that divisions based on raised beaches are more detailed than those based on fauna. The sea-level fluctuated more frequently than the fauna changed, and it affords, therefore, one good way of defining periods. A change of fauna coincides with the Tyrrhenian 32 m. sea-level, but since this level is of Great Interglacial age and therefore post-Mindel, the gap between the Milazzian and Tyrrhenian would not afford a suitable base-line for the Pleistocene though one of this kind was actually proposed some years ago. The next older faunal break is between the Calabrian and Sicilian levels. Since the Milazzian level is of First Interglacial age, the Günz glaciation seems to fall at the oscillation between the 103 m. and 56 m. sea-levels, and to be contemporary with part of the Sicilian fauna. So far as raised beaches are concerned, a suitable line to mark the beginning of the Pleistocene would be the oscillation prior to the 103 m. sea-level, which is the most widely encountered stage of the Sicilian.

Broadly speaking a physiographical change of importance coincides with the Sicilian. The 103 m. level is one of wide platforms. It suggests long duration of the phase and encroachment of the sea on more or less peneplaned land-surfaces. From then onwards, however, one encounters relatively narrow platforms, suggesting relatively short periods of stable sea-level, and in general an increase in the intensity of relief. A boundary line just prior to the abandonment of the 103 m. sea-level, therefore, would serve well as a lower boundary for the marine Pleistocene.

It would, however, be less satisfactory for continental facies. Since, on the evidence of the Crags, two cold periods which immediately antedate the Cromer Forest Bed must be correlated with the Günz glaciation of the Alps, the Sicilian appears to extend back into the past preceding the Günz glaciation. This is confirmed by a sequence of beach bars and lagoons preserved on the shores of Arabs Gulf, west of Alexandria, northern Egypt (material exhibited in the Institute of Archaeology, studied in co-operation with Mr. Day Kimball and Mr. Roger Summers who stayed in the area for two years). Owing to the rapid advance of the coast-line, the sequence of events between the 103 m. Sicilian beach and the Milazzian one of 56 m. is exceptionally clear. There are no less than four stages of stationary sea-level intercalated between these two, which all oscillated between 100 and 80 metres above the present sea-level. The final drop from 80 to 56 metres is likely to correspond to Günz, therefore, one finds once more that much of the Sicilian—which was of long duration—antedated this glaciation.

The Calabrian and its Villafranchian continental facies precedes the Sicilian. At the present time many geologists tend to hold the view that the Villafranchian should be included in the Pleistocene. This would admittedly have advantages, especially in areas outside Europe, and to some extent even in Europe, as I pointed out as long ago as in 1935. Since then, however, I have become more sceptical, as there are certain difficulties and uncertainties. These, in my opinion, should first be removed by further research, before a decisive step is taken which in a few years' time might raise fresh difficulties.

There appears to be almost universal agreement that the interglacial of the Cromer Forest Bed should be regarded as Pleistocene. It is indeed the First Interglacial of the Continental sequence. It

is preceded by the Günz glaciation of the Alps, and by the invasions of cold fauna manifested in the East Anglian Crags. That the Günz glaciation should be included in the Pleistocene, is I believe the view of the majority of geologists. This means that the Red Crag and all later Crags of East Anglia are of Pleistocene age. The Crags, however, contain a vertebrate fauna which comes close to the Val d'Arno type. As we are considering periods of time which from the geological point of view are exceedingly short, the absence of obvious differentiation in the fauna does not necessarily imply identical age. Since Villafranchian species of mammalia survived in numbers up to the beginning of the Mindel glaciation (such as *Machairodus*, *Equus stenonis* group), the presence of such " Villafranchian " types need not make the containing deposit pre-Pleistocene. The difficulty is simply that we are dealing with a transitional period, and that the fauna did not change abruptly at the beginning of the Günz glaciation. If the fauna is the only indication of the age of a deposit, therefore, it is almost impossible to draw a stratigraphical boundary line in practice. This is so especially because the newly-appearing species which may be regarded as " Pleistocene " by definition are often rare in faunal assemblages. The easiest way out, therefore, might seem to be to include the whole of the Villafranchian in the Pleistocene.

Now, the Villafranchian *sensu stricto* is based on the section of Villafranca d'Asti, not far from Turin, and more sections from this phase have been described from Italy than from any other country, among them the important one of the Upper Val d'Arno near Florence. Unfortunately, none of these permits of a direct correlation with the Günz glaciation of the Alps, and roundabout methods have to be employed. The most important is provided by the marine equivalent of the Villafranchian *sensu stricto*, *i.e.* the Calabrian, whose fauna contains several mollusca which are restricted to cold seas at the present time. It is conceivable that these species (among them *Cyprina islandica*) have changed their climatic requirements since Calabrian times, a possibility which is apt to be overlooked. But let us assume for the sake of the present argument that this is not the case. Then the Calabrian is contemporary with one or more phases of cool climate. It is only too easy to conclude that these must represent the Günz glaciation. But this glaciation is almost certainly post-Calabrian, *i.e.* contemporary with the later part of the Sicilian of Gignoux. However, Eberl has shown that, in the Alps, Günz was preceded by several earlier cold phases, which are evidenced also by pre-Günzian river terraces in central Europe. Some of these are likely to be contemporary with the evidence of " cold " in the Calabrian.

At the present we do not know enough about these pre-Günzian cold phases to say what the evidence for coolness in the Calabrian really means. But it must not be overlooked that the Sicilian, too, has to be placed in the sequence. Speaking of the Sicilian in the palaeontological sense as established by Gignoux, it includes at least six altimetric stages, of which the first five correspond to sea-levels of about 100 and 80 metres, whilst the last is that of about 60 metres which is best called by its old name, the Milazzian, and which is of First Interglacial age. The five earlier stages of the palaeontological Sicilian cannot but represent a considerable period of time, and the Günz glaciation (which occurred just prior to the First Interglacial) is to be placed somewhere late in the Sicilian. Palaeontological evidence supports this view, since cold forms are conspicuous among the marine mollusca of the Sicilian deposits. On these grounds the East Anglian Crags (except Coralline Crag) may be regarded as Sicilian, though they have not preserved their altimetric position. The fact that the Günz glaciation immediately preceded the First Interglacial, renders it conceivable that an oscillation of the sea-level between the Sicilian 80 m. stage and the Milazzian 60 m. stage is the equivalent of at least the second phase of Günz. This appears to me the interpretation which is most closely in accord with the European evidence. It would mean that the Calabrian (and with it the Villafranchian *sensu stricto*) is wholly pre-Günzian. If one decides, therefore, to include this Villafranchian in the Pleistocene, a considerable period *ante*dating Günz would become part of the Pleistocene. Before such a step is taken it would be advisable to study with care its possible implications.

One such implication is that a period of time would be added to the Pleistocene which is probably several times longer than the Pleistocene without the Villafranchian *sensu stricto*. This is indicated

by several lines of independent evidence. First, the Villafranchian deposits are of very considerable thickness. In the Upper Val d'Arno, there are some 500 feet of fluviatile and lacustrine deposits all attributable to the Villafranchian proper. Similarly, Calabrian deposits are far thicker than the total of deposits known from the Pleistocene in Italy. Even the Sicilian deposits exceed in quantity those of post-Sicilian times.

Secondly the number of phases of high sea-level from the Milazzian to the present day is in the neighbourhood of five, whilst the Sicilian alone comprises five more, not to mention the Calabrian, the altimetric subdivisions of which are still unknown.

Thirdly, the sea-level of the Calabrian was about 200 metres higher than the present. A drop of 100 metres occurred between it and the Sicilian with its five stages. Very considerable denudation of land surfaces occurred during this period. From the beginning of the Sicilian the sea-level dropped another 100 metres (apart from eustatic oscillations), but this drop was accompanied by an increase of topographic relief suggestive of rapid down-cutting while there was not enough time for general denudation to achieve any measure of peneplanation. This again suggests that the Calabrian was longer than the Sicilian plus the Pleistocene.

Lastly, tectonic history suggests that the Calabrian is a far remoter period than what is commonly called the Lower Pleistocene. There is a phase of disturbances which separates the Sicilian from later deposits in Italy, and an earlier one which separates the Calabrian from the Sicilian. Thus, if the Calabrian with its terrestrial equivalent, the Villafranchian *sensu stricto*, be included in the Pleistocene, it is very likely that we increase the duration of this period several times.

There are other difficulties implied in the inclusion of the Villafranchian *sensu stricto* in the Pleistocene. For instance, the terms " Lower, Middle, and Upper " Pleistocene, the use of which is well established in Europe, must be retained. If the overloading of the Lower Pleistocene by the addition of the Villafranchian is to be avoided it would be advisable to call it " Basal," or " Lowermost " Pleistocene, or the like. Nevertheless, should this step prove to have overwhelming advantages it may have to be taken. The crucial problem at the present moment, however, is not merely whether our present knowledge of Plio-Pleistocene deposits is more easily classifiable if the Villafranchian *sensu stricto* is called the Lower Pleistocene. The great question is a twofold one, namely (*a*) is the Calabrian-Villafranchian contemporary with the pre-Günzian glaciations and should these be regarded as Pleistocene? I fear this issue cannot be settled without further research. And (*b*), if (*a*) can be answered in the affirmative, is it advisable to make the Pleistocene several times longer than it is according to our present conceptions?

Thus there are three alternatives for drawing the Plio-Pleistocene boundary line, namely:—

(1) Maintaining the line just at the base of the Günz glaciation, and splitting the Milazzian from the Sicilian *sensu stricto*.

(2) Including the whole of the Sicilian in the Pleistocene and using the unconformity between the Sicilian and the Calabrian.

(3) Using the unconformity at the base of the Calabrian. In view of the fact that our present knowledge is still so inadequate I venture to suggest that the question of the inclusion of the Villafranchian in the Pliocene or Pleistocene be left open for the time being. It is easy to treat the Villafranchian *sensu stricto* temporarily as a transitional phase, calling it neither Pliocene nor Pleistocene.

Now that attention has been drawn to the problem, workers in the field will increasingly pay attention to it, and new results are bound to be produced. It might be profitable to review the position at some future Congress in the light of fresh evidence then available.

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